MONASH University

ACCIDENT RESEARCH CENTRE

ENHANCED CRASH INVESTIGATION STUDY (ECIS)

IDENTIFICATION OF COUNTERMEASURES TO ADDRESS SERIOUS INJURY CRASHES, ECIS REPORT 4.

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FOREWORD

Through sponsorship and support from the Victorian Transport Accident Commission (TAC), the Monash University Accident Research Centre (MUARC) with leading local and international partners established the Enhanced Crash Investigation Study (ECIS).

The ECIS program was designed to provide insight into how serious injury crashes occur, and then, using this information, identify measures that would be effective in preventing occupants of vehicles being seriously injured in the event of a crash.

This *Report*, the fourth in the ECIS Report series, identifies measures that address factors associated with crash occurrence and serious injury. By identifying the full range of currently available countermeasures, as well as those expected to be available as vehicle technology evolves, opportunities to prevent serious injury crashes will be clear. Given this focus, it is anticipated that the findings of this report will be used to inform the development and implementation of road safety action plans aimed at eliminating serious injury crashes.

Keywords: vision zero, safe system, crash, travel speed, impact speed, hospitalisation, serious injury, abbreviated injury scale, MAIS 3+, road safety, crash risk, crash avoidance, contributing factors, crash chain analysis, risk factors.

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The ECIS Investigators express their sincere gratitude to the injured drivers and families who participated in the study. We certainly appreciate that the experience of being involved in a crash and admitted to hospital is extremely traumatic, overwhelming and is a period of great uncertainty. We are eternally grateful that you consented to participate in the ECIS program.

It is through this selfless participation that this report and the ECIS Report Series are possible. The goal of course is that the insight gained and documented here on the causes and consequences of serious injury crashes finds its way into improved road safety policy and practice, including improvements in the design of cars and roads.

Our commitment to you is to work hard on ensuring that the findings of the ECIS program are used to create the safest road transport system possible. Our goal is to eliminate the risk of serious injury in crashes and to ensure every person gets home safely, every time. The lessons we have learned from each crash in the ECIS program will make this possible.

A project of this magnitude and scope is only possible due to many people making invaluable contributions. Organisations and key individuals are noted below.

Transport Accident Commission (TAC)

MUARC acknowledges the funding and logistical support provided by the Victorian Transport Accident Commission (TAC). In particular, we thank the TAC Board and Mr Joe Calafiore (CEO) for supporting the study from the beginning.

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The Alfred Hospital and the Royal Melbourne Hospital

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Participants of Expert Panels, Regional Panels and Safe System Forums

Throughout the study, many members of local government, VicRoads, Victoria Police, the SES, Ambulance Victoria, the TAC, the Department of Health and Human Services, the Department of Justice and Regulation and members of local communities involved in road safety action groups participated in Expert and Regional Panels. Their knowledge and insights of community road safety were invaluable.

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At Monash University

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On a personal note, Associate Professor Michael Fitzharris thanks Mr Richard Jones (Oxford Consulting), Dr Karen Choong (Hawthorn Medical) and Dr Logan Bittinger (Melbourne Heart Care) for their support and assistance.

The ECIS Team

The ECIS team involved many individuals across numerous roles. All who played a vital role in the conduct of the study are listed here.

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EXECUTIVE SUMMARY

REPORT OBJECTIVES

The *Enhanced Crash Investigation Study (ECIS)* was funded by the TAC with two objectives:

1) To provide the TAC with insight into how serious injury crashes occur.
2) To identify crash prevention measures and measures that would be effective in preventing occupants of vehicles being seriously injured once a crash occurs.

Injured drivers admitted to The Alfred Hospital and The Royal Melbourne Hospital were enrolled to the ECIS program. The data collection period for these crashes was mid-2014 to end-2016.

The findings of the ECIS program are presented over four reports, with this being the fourth in the series (see Appendix G). This *Report* presents current and future countermeasures that target specific factors identified as having contributed to the occurrence of crashes and the type and severity of injuries sustained. In doing so, this *Report* meets the second objective of the ECIS program, having examined in detail how serious injury crashes occur in *ECIS Reports 1, 2, and 3*.

UNDERSTANDING THE FIT AND ROLE OF COUNTERMEASURES IN ADDRESSING CRASH OCCURRENCE AND INJURY SEVERITY CONTRIBUTING FACTORS WITHIN THE INTEGRATED CRASH SAFETY CHAIN

Building on *ECIS Report 3*, the identification and analysis of countermeasures was undertaken in line with a modified version of Tingvall's I*ntegrated Safety Chain (*ISC*)*[1] developed for use in the ECIS program (see Figure E.1). The ISC provided a valuable tool to systematically link contributing factors with countermeasures to specific parts of the crash sequence based on their mechanism of action.

Adopting this approach permitted the identification of countermeasures designed to address *Threats to Normal Driving* before drivers even commence their trip, through each point of the crash sequence, to discharge from hospital and re-integration into the community.

Through a significant development process, an extensive library of driver, vehicle, road infrastructure, and post-crash care focused countermeasures was established. The mode of action and functional boundary was defined for each currently available and future countermeasure identified. Together, these represent the field-of-influence of the countermeasure. An estimate of likely efficacy in addressing the identified contributing factor in relevant crashes was also made. Multiple countermeasures may be available and relevant to addressing a single contributing factor.

Countermeasure efficacy ratings were made independent of the potential influence of other crash occurrence and injury severity contributing factors that may be present in a crash. The estimated likely efficacy of each countermeasure was assessed by an expert group based on the specific intent and functional performance boundary of the countermeasure. This was also informed by knowledge of published research where available and an assessment of exemplar crashes.

Whether a countermeasure is *applicable* or *relevant* to a crash is dependent on:

a. Whether its paired contributing factor was present *and* exerted a direct influence on the crash occurring and/or the nature and severity of injuries sustained (see *ECIS Report 3*).
b. Whether the field of influence of the countermeasure overlaps with the identified contributing factor. This overlap can also be expressed as the contributing factor, or more generally the crash, being *sensitive* to the effect of the countermeasure.

By way of example, for a driver involved in a frontal impact crash, frontal airbags are known to be a highly efficacious countermeasure in the prevention of serious head, face, neck, and chest injuries. Whether the fitment of a frontal driver airbag — plus the concurrent optimisation of seat belts and vehicle structural enhancements associated with airbag fitment — is applicable to an ECIS crash is therefore dependent on involvement in a frontal crash; that the vehicle did not have a frontal driver airbag fitted, and the driver sustained injuries to the head, face, neck and/or chest. This is because the prevention or mitigation of these injuries falls within the functional performance range, and hence safety benefit, of driver frontal airbag systems. In this example, these specific driver injuries were considered *sensitive* to the identified applicable

1 Tingvall C. Distraction from the view of governmental policy making subsection of the chapter: Government and industry perspectives on driver distraction. In: Regan M, Lee J, Young K, editors. Driver distraction: Theory, effects, and mitigation. Melbourne: CRC Press; 2008.

PHASE	DEFINITION AND INTERVENTION APPROACH	INTERVENTION GOAL
1. Threats to Normal Driving	• Driver (D), Vehicle (V), and Road Infrastructure/Environment (E) factors detrimental to *Normal Driving*, including factors that pre-dispose a driver to a crash or act to negatively impact driver ability to respond and avoid a crash. • D: intoxication and/or use of illicit drugs, abuse of prescribed medication; medical/health condition; experiential factors (new licence, presence of peers), offence/crash history; V: vehicle condition/roadworthiness including tyre tread and lighting systems; E: signage, road geometry, latent (in-built) risk by design. • The goal is to eliminate the presence or manage the influence of these threats.	**Measures to address human, vehicle & road environment factors detrimental to *Normal Driving***
2. Normal (Routine) Driving	• *Normal Driving* is characterised by the control of the vehicle by a driver in a manner that is responsive to the road environment, surrounding traffic and other road users such that a trip is successfully completed as planned and without conflict/incident. *Normal Driving* includes compliance with traffic laws. • Per the *Safe Driver* element of the *SRA Model of a Safe Road Transport System*[2], the prerequisites for *Normal Driving* are: seat belt worn (i.e., use of protective equipment); driving within the speed limit; non-use (handling) of mobile phone; BAC within limit for licence class; no illicit drugs used or abuse/non-prescribed use of benzodiazepines and/or opioid-based analgesics; no excessive drowsiness.	**Measures to promote and return a driver to *Normal Driving***
3. Deviation from Normal Driving	• Driver (human) factors causing a shift from *Normal Driving*. In addition to the prerequisites of *Normal Driving* not being met (excluding impairment factors present prior to the commencement of driving (Phase 1: Threats), the driver/vehicle deviates from a safe travel path due to driver performance failure(s) (e.g., error), the effect of health and driver state factors, and/or non-compliant behaviour; these factors can result in a failure to recognise roadway cues and the presence of other road users/objects resulting in an *Emerging Situation* if not corrected. • Intervention approach: provide information and support (includes warning).	
4. Emerging Situation	• Vehicle is in a position sufficiently beyond *Deviation from Normal Driving* to be a direct threat to the driver (and other road users) if left uncorrected. • Movement depends on crash type: midblock/lane departure involves a drift/deviation/move from travel lane; intersection: lack of proper response to traffic control signal and/or on-coming vehicle. • Intervention approach: warning and intervention in driving.	
5. Critical Situation	• Crash event is imminent due to non-response or ineffective response to the threat of the *Emerging Situation.* • Trajectory of vehicle: in-path of other road user, entered shoulder/off-roadway, non-response to stationary vehicle. • Intervention approach: immediate and active correction.	
6. Crash Unavoidable	• Crash is imminent with the time-to-collision (and vehicle trajectory) so short as to make the crash unavoidable. • Intervention approach: preparation for the crash with a view to controlling the level of crash energy and optimising vehicle safety systems to minimise crash energy and preparing the driver/vehicle safety systems for impact.	**Energy reduction and injury mitigation measures**
7. CRASH	• Injury mitigation through the effective control and management of crash energy. • Intervention approach: measures aimed at vehicle crashworthiness and road engineering solutions to manage impact speed, energy transfer, and energy dissipation. Includes measures to prevent secondary impacts, the prevention of vehicle rollover events and/or impacts with non-frangible roadside objects.	**Injury mitigation measures/energy dissipation**
8. Ambulance & Hospital Care	• Emphasis is on systems, processes, and training to enable an optimal outcome for the injured driver to be achieved. • Intervention approach: stabilisation, extrication and transport of the injured driver and the provision of rapid and efficacious trauma care in the hospital setting.	**Immediate post-crash emergency care, retrieval, and acute hospital trauma care**
9. Rehabilitation, Recovery, Injury/other Insurance	• Care and access to services following acute treatment for injuries. • Intervention approach: processes and programs to facilitate recovery and achievement of optimal health, function, and re-integration to everyday life post-crash and beyond the hospital setting.	**Rehabilitation, supported recovery and community integration**
10. Crash Data Systems	• Vehicle (on-board) data systems to capture critical pre-crash and in-crash data, enabling understanding of crash circumstances, occupant injury risk factors and effects of safety systems. Data collected via in-depth crash investigation. • Integrated administrative crash data, emergency service and hospital-based data systems required to monitor system performance and monitoring of road trauma. • Required for the development of road safety strategy and action plans.	**Fitment, access, collection, and reporting**

FIGURE E.1 INTEGRATED SAFETY CHAIN USED IN THE ECIS SAFE SYSTEM FAILURE ANALYSIS

2 Stigson H. A Safe Road Transport System - Factors Influencing Injury Outcome for Car Occupants. Stockholm Sweden: Karolinska Institute; 2009. The SRA Model of a Safe Road Transport System operationalises the Vision Zero Multi-Dimensional Model for Safe Travel. 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.

countermeasure. In this case, the efficacy rating of *high* is based on their observed benefit in mitigating the serious head, face, neck, and chest injuries in frontal crashes.

This assessment was completed for every risk factor identified in each crash using the established countermeasure library, which included 278 countermeasures. The assessment of the applicability of a countermeasure for each contributing factor was completed for each ECIS crash on a case-by-case basis. This ensured that a consistent and systematic approach was used across each ECIS crash. Adopting this approach also provides a comprehensive systems-based analysis of all currently available countermeasures that can play a role in reducing the incidence and severity of road trauma. Future Advanced Driver Assistance Systems (ADAS) were also included.

The primary analysis outcome of this *Report* is the proportion of hospitalised ECIS case drivers that each countermeasure will influence. By using the ISC, the point of effect of each countermeasure in the crash sequence can be seen (Figure E.1). This point of effect reflects the intent and functional boundary of the countermeasure. An efficacy rating and time horizon variable provides a further basis for assessing the potential of countermeasures to reduce serious injury road trauma.

IDENTIFYING EFFECTIVE INTERVENTIONS TO ACHIEVE NORMAL DRIVING, THE MANAGEMENT OF ENERGY AND THE ELIMINATION OF SERIOUS INJURY

Mobility, the ability to go about daily life, the movement of goods, and the delivery of services is a central function of the road transport system. The findings of the ECIS program demonstrate that this comes at an immense human cost. Crashes and the associated injuries can be severe, and life changing.

The importance of providing a safe road transport system is obvious.

Despite this, the ability to achieve a safe system has proven challenging for a host of reasons. In articulating *Vision Zero,* Tingvall highlighted the preference given to mobility over human safety. Plotting a different path and drawing on the work of Haddon and others from the field of impact biomechanics, Tingvall argued that not only was the mitigation and eventual elimination of serious injury an ethical imperative, but that by designing the system appropriately it is possible. Tingvall's formulation of the inherently safe road transport system stated that once pre-identified *Safe Driver, Safe Vehicle, and Safe Road* system design criteria were met, no person would be seriously injured in a crash. The analysis presented in *ECIS Report 1* demonstrated this to be the case.

Beyond meeting specific design criteria of the road transport system, the elimination of serious injury is dependent upon the success of primary and secondary prevention measures. The ISC (Figure E.1) provides a conceptual framework that can be used to identify crash prevention and injury mitigation countermeasure opportunities across the entire crash sequence. Tingvall's ISC[3] presents the crash sequence as a series of phases as the driver shifts from *Normal Driving* to having a crash. This was expanded for application in the ECIS program to include *Threats to Normal Driving,* post-crash care, and data systems.

Each phase of the ISC represents a countermeasure intervention point. Depending on the phase, countermeasures are focussed on either crash prevention through addressing *Threats to Normal Driving,* the restoration of *Normal Driving* (i.e., pre-crash), injury mitigation through the effective management of crash energy (i.e., crash), or the management of the injured driver following the crash (i.e., post-crash).

The concept of *Normal Driving* is integral to the ISC. *Normal Driving* represents the non-conflict phase of driving and is where drivers spend most of their time.[4] Ideally, a driver would spend the entirety of their trip in this phase. Doing so would result in the completion of a trip without conflict or incident. *Normal Driving* has also been referred to as baseline, routine, and uneventful driving,[5,6,7] benign and uneventful driving,[8] and

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3 Tingvall C. Distraction from the view of governmental policy making. Subsection of the chapter: Government and Industry Perspectives on Driver Distraction. In: Regan M, Lee J, Young K, editors. Driver distraction: Theory, effects, and mitigation. Melbourne: CRC Press; 2008.

4 Eugensson A, Ivarsson J, Lie A, Tingvall C. Cars are driven on roads, joint visions and modern technologies stress the need for co-operation. 22nd Enhanced Safety of Vehicles (ESV) Conference (ESV 2011); 13-16 June 2011, Washington, DC, USA. Paper Number 11-0352.

5 'Normal Driving has previously not been well defined however has been labelled baseline, routine, uneventful, typical, ordinary; see: Papazikou E, Quddus M A. Thomas, P. Detecting deviation from normal driving using SHRP2 NDS data. 96th Annual Meeting of the Transportation Research Board (TRB), Washington D.C., US, 8th-12th January 2017.

6 Klauer SG, Dingus TA, Neale VL, Sudweeks JD, Ramsey DJ. The impact of driver inattention on near-crash/crash risk: an analysis using the 100-car naturalistic driving study data (Report No. DOT HS 810 594). Washington, DC: U.S. Department of Transportation; 2006.

7 Olson RL, Hanowski RJ, Hickman JS, Bocanegra J. Driver distraction in commercial vehicle operations (Report No. FMCSA-RRR-09-042). Washington, DC: U.S. Department of Transportation; 2009.

8 Kanianthra, J. Re-inventing safety: Do technologies offer opportunities for meeting future safety needs? SAE Technical Paper 2006-21-0009; 2006.

safe driving.[9,10,11] The ISC explicitly recognises, however, that deviations from *Normal Driving* occur. Whether the shift from *Normal Driving* results in a crash-relevant conflict, a near-crash event, or an actual crash[12] depends on the success or otherwise of countermeasures designed to return the driver back to *Normal Driving*. While managing shifts from *Normal Driving* is essential to crash avoidance, proactive measures can also be implemented to support *Normal Driving*; for instance, building road infrastructure following the principles of self-explaining roads that support driver decision-making.

Failure of crash prevention measures results in progression towards a crash where the mitigation of injury becomes the sole focus, after which survival and achieving an optimal recovery and return to pre-crash life and independence becomes the goal. This is, in essence, what the ISC crash sequence model seeks to operationalise.

The definition of *Normal Driving* is therefore critical as it provides the basis for defining shifts toward conflict situations. For the purposes of this *Report, Normal Driving* is defined as:

1. The control of the vehicle by a driver in a manner that is responsive to the road environment, surrounding traffic and associated traffic flow, and other road users. *Normal Driving* includes being responsive to any potential threat, including that posed by another road user. *Normal Driving* is therefore highly contextual.
2. Compliance with all traffic laws, inclusive of compliance with and/or responding appropriately to traffic signs/signals (i.e., traffic lights) including advisory signs.

Following Tingvall, prerequisites of *Normal Driving* were adopted. The prerequisites of *Normal Driving* represent the design criteria, or boundary, around which safety interventions can be reasonably defined and implemented. These included: seat belt worn; driving within the speed limit; non-use (handling) of a mobile phone; having a BAC within the permissible limit for the licence class of the driver; non-use of illicit drugs or abuse/non prescribed use of benzodiazepines and/or opioid-based analgesics; no excessive drowsiness.

Adopting this approach recognises that the successful undertaking of a trip is influenced by factors before the trip commences. These are referred to as *Threats to Normal Driving,* seen as Phase 1 of the ISC (Figure E.1). These can be driver (e.g., impairment due to alcohol), vehicle (e.g., tyre condition) or road infrastructure (e.g., pavement surface) factors that contribute to crash occurrence. Countermeasures seek to address the threat posed by these factors. The analysis presented in *ECIS Report 3* highlighted the significant need for countermeasures that address these threats, while the findings of this *Report* highlight the numerous currently available and foreseeable countermeasures to do so.

Within the trip itself, *Deviations from Normal Driving* (Phase 3) if left unchecked lead to *Emerging Situations* (Phase 4) and then *Critical Situations* (Phase 5), to a point where a crash becomes Inevitable (Phase 6). Countermeasures, whether they be driver-focussed, vehicle-technology, or road infrastructure-based, have the objective of encouraging, assisting, and/or actively intervening to force the driver back to return to a state of *Normal Driving*. These measures address driver acts and decisions, whether they were done in error, were unintentional, or were deliberate acts of non-compliance. These measures, of which there is at least one matched to each contributing factor, have a crucial crash prevention role. Countermeasures also play a crucial role in mitigating the severity of injury once a crash occurs. This analysis shows that there are effective countermeasures at each point of the crash chain.

The analysis presented in this *Report* demonstrates that the concept of safety-by-design is critical. The ability of driver, vehicle, and infrastructure countermeasures to work together to address the full range of contributing factors is integral to the safety of road users. The successful application of many of the vehicle-based technology measures will be dependent not only on the capability of sensor technology fitted on vehicles, but the capacity for vehicles to interact with one another and with the road infrastructure through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology, respectively.

The complexity and multitude of factors that lead to drivers being in the position where a crash is inevitable means that complete elimination of crashes is highly improbable, at least for many decades to come. This is the case since currently available crash prevention countermeasures range in their efficacy from low-to-high, with no single countermeasure likely be 100% successful all of the time. Aligning available countermeasures to

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9 Sunnevång C. Characteristics of nearside car crashes – an integrated approach to side impact safety. Umeå, Sweden: Umeå University 2016.

10 The Report authors view *Safe Driving* to be an outcome of the exercise of *Normal Driving*.

11 From 2026, EuroNCAP and ANCAP assessment protocols will be defined to reflect four distinct phases of a potential collision and crash, these being: Safe Driving; Crash Avoidance; Crash Protection; Post-Crash Safety. see: EuroNCAP. Euro NCAP Vision 2030: a Safer Future for Mobility. Leuven, Belgium: EuroNCAP; 2022. This is consistent with the characterisation of the driving process of the *Integrated Safety Chain* (ISC) adopted in this Report.

12 A crash-related conflict, a near-crash event, and a crash are sub-types of Safety Critical Events (SCE); see Glossary and Abbreviations of this Report.

address the current crash problem is therefore imperative, although so too is investing in future countermeasures identified in this *Report*.

Recognising the limits of primary prevention and the need to prevent drivers (and vehicle occupants) from being injured, an array of efficacious vehicle and infrastructure injury mitigation countermeasures have been developed. The need for these countermeasures is demonstrated not only by the number of road users killed in Victoria[13] but the high injury acuity of drivers involved in crashes examined in the ECIS program. Indeed, of the drivers hospitalised and enrolled to the ECIS program, approximately half sustained MAIS 3+ injuries, the average length of stay in hospital was nine days, and nearly 40% required further care and rehabilitation. In the 393 crashes examined, 18 people died in 17 crashes.

Central to the prevention of serious injury is the need to understand how injuries occur and why. This understanding leads to the development and implementation of injury control measures. Since the time of Haddon[14] – and even before – the limited tolerance of the human body to withstand the level of forces experienced in a crash is well known. Protecting drivers from injury is therefore about ensuring that the system is operated within well-defined boundaries. This requires that the vehicle and road infrastructure be designed to manage and absorb crash (i.e., kinetic) energy so that the driver is protected from serious injury.[15] This is the core principle of *Vision Zero* and underpins the *Safe System* approach (see *ECIS Reports 1, 2*). In practical terms, measures which facilitate this include vehicle crumple zones, energy absorbing vehicle structures and infrastructure measures such as flexible barriers. These measures focus on controlling how injury causing kinetic energy (KE) dissipates in the crash and how much is left for the driver's body to absorb directly.

Analysis of the ECIS data as reported in *ECIS Reports 1, 2 and 3* demonstrated that the level of energy in the road transport system as currently operated is too high, and that when crashes occur, the impact speeds seen are well beyond the ability of even the safest currently available vehicle to protect drivers from serious injury. Indeed, the analysis points to the primacy of managing impact speed in reducing the incidence of serious injury. This *Report* identifies high efficacy road infrastructure and vehicle-based countermeasures relevant to a high proportion of drivers that address this primary risk factor. This is the countermeasure focus of Phase 6 and Phase 7 of the ISC.

All injured road users require access to emergency and acute care (Phase 8), after which, supportive care and associated services to assist the injured driver to return home and resume their pre-crash way of life are required (Phase 9). A host of measures ranging from the rapid transport of injured drivers to hospital for definitive care through to managing the impacts of trauma were identified.

The range of countermeasures identified in this *Report* is extensive. This reflects the complexity of why crashes happen, and the factors associated with injury. The following section highlights selected high efficacy countermeasures and the proportion of drivers to which they are applicable. These data, as well as that provided in Chapters 3 to 8, can be used as the basis for taking the necessary steps to reduce road trauma in Victoria.

KEY FINDINGS: HIGH EFFICACY COUNTERMEASURES APPLICABLE TO SERIOUS INJURY CRASHES

The following series of Tables (E.1, E.2, E.3, E.4) highlight selected high efficacy currently available countermeasures and the proportion of drivers to which they are applicable. By presenting these in the rank order of the proportion of ECIS case drivers to which they relate, an understanding of high priority driver-focussed, vehicle-focussed, road and road infrastructure-focussed countermeasures can be gained.

The objective in highlighting these countermeasures is to draw attention to those that can make a substantive difference to the level of hospitalisation severity road trauma in Victoria. This *Report* identifies multiple countermeasure opportunities across the crash sequence, each with a different focus. Implementation of a suite of carefully selected countermeasures is likely to be required given the number and extreme spread of contributing factors associated with these crashes.

In assessing countermeasure priorities, it must be recognised that while high efficacy vehicle safety countermeasures are being fitted to new vehicles, the vehicle turnover rate and rate of vehicle attrition means

13 https://www.tac.vic.gov.au/road-safety/statistics/lives-lost-annual
14 Refer to ECIS Report 1 for detailed examination of Haddon.
15 In the crash phase vehicle-based and infrastructure measures are focussed exclusively on the prevention of serious injury. The design principle is that the vehicle speed and the posted speed limit be in accordance with the capacity of the vehicle and the infrastructure to protect the driver (and other occupants). See ECIS Report 1 for full discussion of this point and the vehicle safety envelope concept. Kinetic Energy (KE) which is proportional to the square of the speed and the mass of the struck/striking vehicle or characteristics of the object struck (e.g., frangibility of pole/tree); the type and severity of injury is also influenced by the location of impact on the vehicle. With impact speed linked to the speed limit by shaping driver speed choice (see ECIS Report 2), this link between crash energy and injury severity is the basis for Tingvall asserting that speed acts as an overall regulator of the level of safety in the road transport system.

that it will likely take up to 29 years for all passenger vehicles to be fitted with the technology of today.[16] For this reason, every effort must be made to ensure that these technologies are regulated as standard equipment in all vehicles as expeditiously as possible. Consequently, the concurrent implementation of driver-focussed and road infrastructure countermeasures will be critical to reducing the level of serious injury that is currently seen.

Examination of the data and countermeasures in these Tables highlighted the importance of vehicle technology and infrastructure solutions in supporting and protecting drivers. The findings also highlight the primacy of speed management in the safe operation of the road transport system. These measures address not only driver travel speed but impact speed and associated crash energy that is directly associated with injury severity. Given the critical role that speed plays in dictating the overall safety of the road transport system — and the suboptimal way that each element (i.e., driver, vehicles, road infrastructure) of the current road transport system performs — these findings are unsurprising. What is clear from these data is that implementation of these measures would have a profound impact in reducing the number of drivers and other road users seriously injured in crashes.

The findings presented in Chapter 3 through Chapter 8 also highlight many currently available medium efficacy countermeasures. It is important to implement these they are applicable to a high proportion of injured drivers. This is especially the case for those that address contributing factors for which high efficacy intervening countermeasures are not currently available, for instance those that address driver drowsiness and driver distraction. Each countermeasure represents an opportunity to reduce the number of drivers (and other vehicle occupants) involved and seriously injured in a crash. Likewise, low efficacy countermeasures that are applicable to a medium-to-high proportion of crashes ought not to be ignored, particularly if they are inexpensive to implement.

Countermeasures expected to be available in the short-to-medium term were also identified. These include measures not presently implemented but where expertise exists to do so, as well as measures that will require significant technical advancement. These represent important crash prevention and injury mitigation opportunities and ought to be pursued with vigour.

For instance, future ADAS implemented through V2V and/or V2I communication technology offer significant promise in improving safety. Early and urgent regulatory efforts to ensure the continued development and rapid fitment of these technologies into future vehicles is needed, particularly in the context of the slow rate of vehicle turnover and the time taken for these technologies to penetrate the entire vehicle fleet. Likewise, there are a range of driver-focussed countermeasures that ought to be implemented.

It is also important to stress that countermeasures are required to be implemented across the crash sequence. This is because each countermeasure addresses a specific contributing factor that places stress on a different part of the crash sequence. Furthermore, no single countermeasure is 100% efficacious. Hence, every effort ought to be made to address *Threats to Normal Driving* and deviations from *Normal Driving* as they occur, thereby eliminating a potential conflict situation as early as possible. Ideally, early intervention to correct shifts in *Normal Driving* would ensure drivers would not be exposed to a crash at all. Crash events are indeed rare events; however, their consequences can be severe and life changing. It is for this reason that the road transport system must be designed and operated in such a way as to protect road users from serious injury when crashes do occur. Specific measures that control and manage crash energy with the goal of protecting the driver are required. It is argued that to achieve an inherently safe road transport system that is truly forgiving of error, there needs to be some redundancy built into the crash chain. For this reason, the judicious selection of countermeasures across each phase in the ISC is appropriate.

There are a number of countermeasure options to address a specific contributing factor. These are clustered together. Decisions can be made on which is most suitable given other policy considerations in the planning process.

16 Natural turnover is occurring now, however full fleet penetration will occur beyond the medium-term. This reflects the age distribution of the passenger car fleet, current vehicle turnover, and attrition of the fleet. From the time a new vehicle technology is introduced and fitted to all new vehicles sold, full fleet penetration can take 29 years; see: Fitzharris and Stephan (2013). Assessment of the need for, and the likely benefits of, enhanced side impact protection in the form of a Pole Side Impact Global Technical Regulation (see: https://wiki.unece.org/download/attachments/15237355/PSI-RD-06.pdf?api=v2).

TABLE E.1 CURRENTLY AVAILABLE DRIVER-FOCUSSED HIGH EFFICACY MEASURES (SELECT MEASURES) [ORDERED BY MAIS 1+ %]

ISC Phase†	Contributing factor to crash / injury	Countermeasure	Drivers sensitive to intervention	
			MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) %
3	Exceed speed limit	Speed enforcement	27.0%	36.2%
3	Exceed speed limit	Speed assistance – Intelligent Speed Assist (intervening)	27.0%	36.2%
1	Traffic offence (speed), last 12-months	Speed assistance – Intelligent Speed Assist (intervening, retrofitted)	24.8%	23.4%
1	Impairing effects of illicit drug use on driving (all substances)	Enforcement (generalised, site specific) plus community education, and associated sanctions	12.8%	17.6%
1	Impairing effects of alcohol (BAC)	Enforcement (and associated sanctions), supported with community education	11.3%	13.8%
1	Impairing effects of alcohol (BAC)	Active (manual) alcohol interlock (intervening)	11.3%	13.8%
3	Seat belt not worn	Enhanced (targeted, intense) enforcement coupled with public education (includes sanction effect component for offenders)	6.8%	7.4%
3	Failure to detect parked vehicle / objects on side of roadway	Object detection (including night vision assist & 360° surround view monitor with Head-Up Display (HUD)	4.3%	1.1%
3	Inattention in the form of using mobile phone	Enforcement - Mobile phone camera detection systems	3.8%	4.8%
1	Impairing effects of illicit drug use on driving (all substances)	Enforcement (expand roadside testing to include additional illicit substances) plus public education	1.8%	2.1%

† See Figure E.1.

TABLE E.2 CURRENTLY AVAILABLE VEHICLE-FOCUSSED HIGH EFFICACY MEASURES (SELECT MEASURES) [ORDERED BY MAIS 1+ %]

ISC Phase†	Contributing factor to crash / injury	Countermeasure	Drivers sensitive to intervention MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) %
7	Frontal impact crash	Measures to improve frontal impact occupant protection safety (inclusive of review of ADR69 / ADR73 for performance requirements)	68.8%	68.6%
5	Braking system suboptimal – frontal collision trajectory	Autonomous Emergency Braking (AEB) – includes all types, including Junction AEB; relies on other braking systems to be fitted (see body of *Report)*	67.0%	64.4%
5	Vehicle deviated (departed) from lane / beyond centre of lane	Automated Lane Keep Assist (ALKS): intervening for oncoming traffic crash mitigation	47.3%	53.7%
7	Impact speed exceeded safety envelope of vehicle	Reduce impact speed via Autonomous Emergency Braking (AEB) – includes all sub-types; relies on other braking systems (see body of *Report)*	43.0%	51.6%
7	Impact speed exceeded safety envelope of vehicle	Replace 4-star or lower safety ANCAP rated vehicles with 5-star safety rated vehicles [assumes no change in speed limits][#]	22.0%	23.4%
7	Frontal impact crash – No frontal airbags fitted	Frontal driver airbag (advanced, dual inflation) inclusive of seat belt optimisation	17.5%	19.1%
7	Rollover, with at least 1/4 turn	Rollover protection test (implementation)	16.8%	14.9%
7	Rollover, with at least 1/4 turn	Rollover injury mitigation countermeasures (i.e., seat restraint, roof padding / roof airbag / centre-line airbag)	16.8%	14.9%
7	Frontal impact crash – Narrow frontal offset (loss of compartment integrity)	Improved frontal impact occupant protection associated structural enhancements to comply with the Narrow Frontal Offset test.	16.6%	19.7%
7	Side impact airbag sensitive crash - No head protecting airbags	Head protecting side curtain airbag (with seat belt optimisation, structural enhancements)	16.0%	21.3%
7	Side impact airbag sensitive - No thorax (including combination thorax- head) airbags	Thorax protecting side airbags (with seat belt optimisation, structural enhancements)	15.0%	20.2%
7	Side impact airbag sensitive, with front left passenger present	Centre-airbag in vehicle (front-through-rear seats)	7.0%	5.9%
7		Centre-airbag in vehicle (front-only)	6.5%	5.9%
7	Side impact airbag sensitive - impact with narrow object (tree, pole)	Measures to improve side impact protection (driven by pole side impact test, ADR 85)	5.3%	6.4%

† See Figure E.1.
Note: EDR uniform requirements and fitment not presented in Table (see Chapter 8).
The risk factor being addressed is that the impact speed occurred above the safety envelope of the vehicle in the ECIS crash of interest. Efficacy for this measure is associated with vehicle replacement such that were the crash to happen as was in the ECIS crash, the impact speed would be within the safety envelope of the 5-star safety rated vehicle and hence the driver would be protected from serious injury. Mechanism via natural attrition or incentivised vehicle replacement scheme.

TABLE E.3 CURRENTLY AVAILABLE ROAD AND ROAD INFRASTRUCTURE-FOCUSSED HIGH EFFICACY MEASURES (SELECT MEASURES) [ORDERED BY MAIS 1+ %]

ISC Phase†	Contributing factor to crash / injury	Countermeasure	Drivers sensitive to intervention MAIS 1+ (N = 400) %	Drivers sensitive to intervention MAIS 3+ (N = 188) %
7	Impact speed exceeds safety envelope of vehicle	Reduce impact speed through reduction in the speed limit#	67.3%	80.3%
	Impact speed exceeds safety envelope of vehicle	Crash location-specific infrastructure measures to prevent collision (e.g., traffic calming measures) and address dissipation of crash energy and/or impact direction (angle) (detail in *Report*, see below for high-efficacy examples)‡	67.3%	80.3%
7	Deviated from lane	Install barrier to address crash event movement and crash energy inclusive of perceptual measures and audio-tactile measures# (qualifier: feasible)	35.3%	46.3%
	Deviated from lane	Speed limit reduction required if elect not to install barrier (subset of above; given current speed limit >= 80 km/h)	25.5%	31.4%
7	Vehicle crossed centre line, head-on crash	Install centre barrier (with 2+1 assessment); inclusive of perceptual measures#	23.8%	39.4%
1	Latent risk due to road design	Comprehensive overhaul of road infrastructure including speed limit revision	22.0%	20.7%
5	Condition of shoulder poor (associated with vehicle movement)	Seal/extend shoulder inclusive of perceptual measures# (qualifier: feasible); remove objects, rollover trip hazards, cover drains	21.8%	27.1%
7	Presence of, and impact with unprotected tree	Install appropriate crash-absorbing barrier guard	21.8%	26.0%
7	Cross traffic/turn	Install roundabout (qualifier: feasible) to prevent conflict, change impact angle, reduce impact speed; inclusive of vertical deflection	19.0%	18.1%
7	Vehicle departed road to left	Install left barrier inclusive of perceptual measures# (with 2+1 assessment)	18.3%	22.9%
7	Cross traffic/turn	Install roundabout with traffic signals (volume/ road function based); includes vertical deflection	9.8%	5.9%
1	Road alignment and/or intersection misleading	Correct alignment and/or remove relevant building/structure if feasible	8.8%	6.4%
4	Enter intersection (failed to recognise intersection)	Install traffic lights; inclusive of vertical deflection with other perceptual measures as required	7.8%	6.4%
7	Vehicle crossed centre line and departed road to right	Install right barrier inclusive of perceptual measures# (with 2+1 assessment)	7.5%	11.2%
1	Pavement surface, negative impact stability/friction	Improve road surface (i.e., grade-unsealed, improve friction, defects, drainage)	6.3%	5.3%
7	Deviated from lane	Reduction in speed limit (in lieu of barrier installation assessed as not being feasible); inclusive of perceptual measures#	6.3%	7.4%
7	Entered carriageway/ turned across (crash incompatible angle, high impact speed)	Side Road Activated Speed (SRAS) systems (enter-carriageway) (no traffic lights present) with associated perceptual measures	5.0%	6.9%

† See Figure E.1. ‡ Percent of crash locations where one or more infrastructure countermeasure was identified. # Inclusive of audio-tactile lane delineation measures (ATLM), lane delineation (painted centre/edge line) and raised reflective pavement markers (RRPMs) or other fluorescent measure for visual guidance (combination). # Further detail of crash locations provided in Appendix E.

TABLE E.4 CURRENTLY AVAILABLE POST-CRASH HIGH EFFICACY MEASURES CURRENTLY (SELECT MEASURES) [ORDERED BY MAIS 1+ %]

ISC Phase†	Contributing factor to crash / injury	Countermeasure	Drivers (crashes) sensitive to intervention MAIS 1+ (N = 400) %	Drivers (crashes) sensitive to intervention MAIS 3+ (N = 188) %
8	Injured driver required emergency response, transport, treatment, and acute care	Provision and resourcing of Emergency Medical Services (EMS) (inclusive of Helicopter-EMS) (HEMS) and acute care trauma services	100%	100%
9	Medical and other expenses incurred, including potential loss of earning	TAC no-fault claims support (inclusive of medical and like support, income support, return-to-work, return-to-health, and community support for independence where appropriate)	100%	100%
9	Involvement in hospitalisation crash (surviving driver)	Early (and repeated) screening for pain, mental health conditions and/or psychological distress (inclusive of self-harm and use/misuse of alcohol and other drugs), with on-going support	99.8%	99.5%
9	Discharged directly home from acute care hospital	Home discharge planning, inclusive of out-patients, allied health and community care where required	58.5%	33.5%
8	Injured driver required emergency response, transport, treatment, and acute care	Accident Emergency Call System (AECS) / eCALL (based on crash location)	42.0%	53.7%
9	Admission to a Rehabilitation centre following acute hospital stay	Resourcing of rehabilitation care and support for re-integration home	41.3%	66.0%
9	Driver sustained fractures (AIS 2+) of the lower extremities and pelvis	Support / programs for persons with fractures (AIS 2+) of the lower extremity and pelvis	34.0%	49.5%
9	Driver sustained mild TBI (based on initial GCS)	Support / programs for persons with mild Traumatic Brain Injury (TBI)	24.5%	31.9%
9	Driver sustained fractures (AIS 2+) of the upper extremities	Support / programs for persons with fractures (AIS 2+) of the upper extremity	19.5%	29.8%
8	Difficult extrication of occupant from vehicle (damage, vehicle orientation/position)	Further ongoing resourcing / training of EMS to provide advanced clinical care	17.5%	26.6%
8	Difficult extrication of occupant from vehicle (damage, vehicle orientation/position)	Further ongoing resourcing of EMS to facilitate extrication of trapped occupants, including access to ISO17840 compliant vehicle Emergency Response Guide (ERG) rescue sheets	17.5%	26.6%
9	Driver sustained serious (AIS 3+) injuries of the spine / spinal cord	Support / programs for persons with serious (AIS 3+) injuries of the spine / spinal cord	6.5%	13.8%
8	Delayed notification and/or difficulty locating due to access/remote location	Accident Emergency Call System (AECS) / eCALL	5.5%	8.5%
9	Driver sustained severe and moderate TBI (based on initial GCS)	Support / programs for persons with severe and moderate Traumatic Brain Injury (TBI)	5.3%	9.0%
9	Involvement in a fatality crash	Mental health support specific to involvement in fatality crash, including family support	4.3%	6.4%
9	Further admission to an acute hospital for additional treatment and/or specialist care, with associated rehabilitation and re-integration home	Resourcing of specialist acute services for management of Traumatic Brain Injury (TBI) and Spinal Cord Injury (SCI)	3.3%	4.8%
8	Prolonged transport; including first attendance at non-trauma centre	Further ongoing resourcing of EMS / acute services to facilitate rapid transport to definitive care	3.0%	3.7%

† See Figure E.1. # Drivers injured in work-related crashes may also access support through WorkSafe, noting TAC provides coverage for all injured drivers in Victoria in the first instance. Among ECIS injured drivers, 6.2% were involved in a work-related crash.

APPLICATION OF FINDINGS, ASSUMPTIONS AND LIMITATIONS

The ECIS program was purposefully designed to be a study of passenger vehicle drivers hospitalised after involvement in a crash. It is therefore important that the findings of this *Report* are viewed and communicated with this in mind.

Specifically, the proportion of crashes to which each countermeasure is applicable to, and hence their rank order, reflects the presence of factors associated with the crash event and factors associated with injury observed in the ECIS sample. As such, the findings reflect the drivers included in the ECIS sample; consequently, the study inclusion criteria must be considered when seeking to translate these results to other contexts.

A systematic, multi-step process using multiple data points across different information sources was adopted to identify contributing factors, upon which countermeasures are based (see Report 3 for detail). This ought to give confidence in the data presented. A detailed discussion of the ECIS method and the sample is described in *ECIS Report 1*.

The data collection period for these crashes was mid-2014 to end-2016. Since this time, the global COVID-19 pandemic (from March 2020 to end 2022) caused significant supply chain disruptions that have negatively impacted on the production and delivery of new vehicles. This would likely exacerbate an already slow fleet turnover with regard to the safety of the overall fleet. Whether changes to travel patterns and vehicle use observed during the COVID-19 pandemic persist remains to be seen. Given the time passed – and with reference to future crashes – it is acknowledged that any change in driver behaviour, the safety of the fleet, and the road infrastructure that may have occurred since the time data collection ceased could impact on the rank order of countermeasures.

To the best of the authors' knowledge this *Report* identifies all available countermeasures applicable to these crashes. An assessment was made as to the efficacy of each countermeasure and its likely availability and implementation time horizon based on existing research and author expertise. It is acknowledged that the countermeasure efficacy may vary depending on the implementation context and at an individual crash level, while time horizon estimates may also change. In addition, countermeasure efficacy is based solely on the effect of the countermeasure in addressing the specified contributing factor and its influence as seen in each ECIS crash. There is no relationship between the countermeasure efficacy rating and cost-effectiveness of implementation, the latter being a policy implementation consideration.

Finally, and as reflected in *ECIS Report 3,* it is acknowledged that the sample size did not support formal statistical testing to compare the presence of a number of crash occurrence and injury severity factors and their associated countermeasures across crash types. With countermeasure identification being the primary point of interest, and the primary outcome being the proportion of serious injury crashes where a specific countermeasure was applicable, such comparisons are largely redundant. However, the reader ought to be mindful of crash/injury countermeasure sub-group analysis where percent values are high but where cell counts are small.

These aspects are important to bear in mind when seeking to apply these findings when setting future road safety priorities.

CONCLUDING COMMENT

This *Report* provides a comprehensive analysis of the countermeasures currently available, and those likely to be available in the short-to-medium term. By identifying countermeasures that address specific crash occurrence and injury severity factors, then giving both their quantum and expected efficacy, it is anticipated that this *Report* represents an invaluable resource for road safety policy makers, the vehicle industry and road designers as they strive to reduce the number of people injured using the road network.

With the goal of achieving reductions in serious injury, and given the multi-factorial nature of crashes, implementation of a suite of carefully selected countermeasures across the crash sequence is likely to be required given the number and spread of contributing factors associated with these crashes. This includes measures aimed at optimising post-crash care and the recovery of injured road users. This is especially important given the significant impact on road trauma on the lives of those injured and their family, friends, and the community more broadly. Hence, the need to adopt a systems approach when developing road safety strategies and action plans that drive the implementation of efficacious countermeasures is clear. Given the scale of serious injury trauma, the implementation of high efficacy countermeasures that can influence a large proportion of the road trauma problem must be prioritised. This includes the further development and implementation of projected high efficacy countermeasures that were identified as being likely to be available in the short-to-medium term.

The need for proactive implementation of vehicle safety regulations and the implementation of driver-focussed and road infrastructure countermeasures is also clear. From an injury causation perspective, a key finding of the ECIS program was that the impact speeds at which crashes are occurring are well beyond the ability of the vehicle to protect occupants from serious injury. This *Report* outlines key opportunities to address this significant risk factor, thereby providing confidence to system operators on ways to manage this threat.

Whilst each driver has a role to play in how they use the road transport system, the critical role of vehicle manufacturers and governments in defining and operationalising the level of safety of the road transport system cannot be overstated. To achieve the long-term goal of eliminating serious injury, significant steps will need to be taken now by governments and vehicle manufacturers in order for future vehicles to have the key safety systems they require to protect occupants from injury. The level of safety afforded to drivers and other road users, is, however, critically dependent on 'built-in' safety of the road and road infrastructure. The analysis of contributing factors demonstrates that these two domains require urgent attention. The range of countermeasures identified in this *Report* highlights the opportunity for these contributing factors to be addressed.

To conclude, when the ECIS program was initiated, it was done so with the expectation of identifying measures that would, once implemented, reduce, and ultimately eliminate serious injury road crashes in Victoria. This *Report* serves this purpose. The insights presented in this Report, as well as those in *ECIS Reports 1, 2 and 3*, represent a unique opportunity to improve the safety of Victorian road users well into the future using data from crashes that occurred in Victoria. It is incumbent that every effort is made to utilise the findings well. Armed with this knowledge, it now falls to all relevant parties with an interest in preventing crashes and serious injury on our roads to act.

MONASH University

GLOSSARY AND LIST OF ABBREVIATIONS

4WD	Four-wheel drive vehicle
AAAM	Association for the Advancement of Automotive Medicine
ABS	Anti-lock Braking System
ACC	Adaptive Cruise Control
ADR	Australian Design Rule
AEB	Autonomous Emergency Braking
AECS	Accident Emergency Call System
AIS	Abbreviated Injury Scale An internationally recognised anatomical-based coding system for individual injuries. AIS severity scores range from 1 (minor) to 6 (untreatable), with the severity level indicating the threat-to-life assuming that the injury in question is the only injury sustained.
ANCAP	Australian New Car Assessment Program
ANPR	Automated Number Plate Recognition
AOD	Alcohol and Other Drugs
AP	Across Path (crash)
ATLM	Audio Tactile Line Marking
ALKS	Automated Lane Keep Assist System
Ax.	Assessment
BAC	Blood Alcohol Content
BEV	Battery Electric Vehicle
BSM	Blind Spot Monitoring
BZ	Benzodiazepines
C-ITS	Co-operative ITS
Crash	A type of Safety Critical Event (SCE). Events where measurable contact between the vehicle of interest and an object (moving or fixed) at any speed occurs. Involves the transfer and dissipation of kinetic energy. This includes contact with other vehicles, roadside barriers, objects on or off of the roadway, pedestrians, pedal cyclists, or animals.
Crash severity	Generic term, also used for the impact severity measures delta-V[2] and EBS
D	Driver, in the context of Safe System Element (SSE)
Delta-V[2]	Vector difference between impact velocity and separation velocity. In lay terms, it represents the change in velocity of the vehicle during a crash event. Delta-V is usually calculated using damage reconstruction software. This calculation requires that the mass and stiffness characteristics of the case vehicle and collision partner must be known. Expressed as km/h.
DMS	Driver Monitoring System
DRL	Daytime Running Lights
DSSAD	Data Storage System for Automated Driving
E	(Road infrastructure) Environment, in the context of Safe System Element (SSE)
EBA	Electronic Brake Assist
EBD	Electronic Brake Force Distribution
ECIS	Enhanced Crash Investigation Study
ECIS-DST	ECIS Safe System Decision Support Tool

ED	Emergency Department
EDR	Event Data Recorder
ELKS	Emergency Lane Keep Assist
EMS	Emergency Medical Services
ESC	Electronic Stability Control
FCW	Forward Collision Warning
FMVSS	Federal Motor Vehicle Safety Standards
GCS	Glasgow Coma Scale
GDL	Graduated Driver License
GLS	Graduated Licensing System
GP	General Practitioner
HEMS	Helicopter Emergency Medical Services
HEV	Hybrid Electric Vehicles
HREC	Human Research Ethics Committee
HUD	Head-Up Display
ICU	Intensive Care Unit
IIHS	Insurance Institute for Highway Safety (United States)
Impact speed	Vehicle speed at impact. Impact speed is relevant to injury severity; therefore, in multi-vehicle crashes a distinction is made between the striking and struck vehicle. This differs from vehicle speed at impact (see below).
Int. Cat.	Intervention category (countermeasure, refer to Table 2.1)
ISA	Intelligent Speed Assist
ISC	Integrated Safety Chain
ISS	Injury Severity Score
KE	Kinetic Energy
Km/h	Kilometres per hour
LBFS	Looked but failed to see
LD	Lane Departure (crash)
LDW	Lane Departure Warning
LKA	Lane Keep Assist
LSS	Lane Support Systems
MAEB	Motorcycle Autonomous Emergency Braking
MAIS	Maximum Abbreviated Injury Scale (score) The highest AIS score in any body region; used as an indication of overall injury severity.
MUARC	Monash University Accident Research Centre
MVC	Multiple Vehicle Crash
NCAP	New Car Assessment Program
Near-crash event	A type of Safety Critical Event (SCE). Scenarios of vehicle-to-vehicle/object conflict where a crash would have occurred had a rapid evasive manoeuvre (i.e., steering, braking, accelerating, or any combination of control inputs) not been made.
OSM	Occupant Status Monitoring

PDO	Property Damage Only (crash)
PDOF	Principal Direction of Force: The PDOF is the angle of the direction of impulse force acting on the vehicle, measured relative to the longitudinal axis.[17] It is represented as an angle (degrees). The PDOF is linked to delta-V.
P-EA	Post-crash: Emergency and Acute Care
PHEV	Plug-in Hybrid Electric Vehicles
P-RID	Post-crash: Rehabilitation, Insurance and Driving-related matters
PTW	Powered two-wheeler (vehicle)
QA	Quality Assurance
R	Road, in the context of Safe System Element (SSE)
RCTA	Rear Cross-Traffic Alert
RI	Rear Impact (crash)
RMH	Royal Melbourne Hospital
RRPM	Raised Reflective Pavement Marker
RWC	Roadworthiness Certificate
S	Speed management, in context of countermeasure intervention
SAS	Speed Assistance Systems
SAE	Society of Automotive Engineers (now SAE International)
SCE	Safety-Critical Event. Following Dingus et al.[18] and Fitch et al.[19], includes: ▪ Crash-relevant conflict: Includes conflicts that are less severe than a near-crash event but beyond the bounds of *Normal Driving;* requires corrective (i.e., evasive) action to avoid escalation to a 'near-crash event. ▪ Near-crash event: Scenarios of vehicle-to-vehicle/object conflict where a crash would have occurred had a rapid evasive manoeuvre (i.e., steering, braking, accelerating, or any combination of control inputs) not been made. ▪ Crash: Events where measurable contact between the vehicle of interest and an object (moving or fixed) at any speed occurs. Involves the transfer and dissipation of kinetic energy. This includes contact with other vehicles, roadside barriers, objects on or off of the roadway, pedestrians, pedal cyclists, or animals.
SD	Standard Deviation
SBR	Seat Belt Reminder system
SI	Side Impact
SRA	Swedish Road Administration, succeeded by the Swedish Transport Administration (Trafikverket)
SRAS	Side Road Activated Speed system
SSE	Safe System Element
SUV	Sports Utility Vehicle
SVC	Single Vehicle Crash
TAC	Transport Accident Commission

17 Johnson NS, Gabler HC. Evaluation of NASS-CDS side crash delta-V estimates using event data recorders. Traffic Injury Prevention. 2014;15(8):827-834.
18 Dingus TA, Klauer SG, Neale VL, Petersen A, Lee SE, Sudweeks J, et al. The 100-Car Naturalistic Driving Study, Phase II - Results of the 100-Car Field Experiment. 2006.
19 Fitch G, Soccolich S, Guo F, McClafferty J, Fang Y, Olson R, et al. The Impact of Hand-Held and Hands-Free Cell Phone Use on Driving Performance and Safety-Critical Event Risk (Report No. DOT HS 811 757). Washington, DC: National Highway Traffic Safety Administration; 2013.

TBI	Traumatic Brain Injury
TPMS	Tyre Pressure Monitoring System.
Travel speed at impact	The speed of the vehicle at the time of impact.
UCSR	Used Car Safety Rating
UN	United Nations
V	Vehicle, in the context of Safe System Element (SSE)
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VMS	Variable Message Sign
VRU	Vulnerable Road User

1 INTRODUCTION

1.1 OBJECTIVES OF THE ENHANCED CRASH INVESTIGATION STUDY (ECIS)

The *Enhanced Crash Investigation Study (ECIS)* was funded by the TAC with two objectives:

1) To provide the TAC with insight into how serious injury crashes occur.
2) To identify crash prevention measures as well as measures that would be effective in preventing occupants of vehicles being seriously injured once a crash occurs.

Injured drivers admitted to The Alfred Hospital and The Royal Melbourne Hospital were enrolled to the ECIS program. The data collection period for these crashes was mid-2014 to end-2016.[20]

The findings of the ECIS program are presented over four reports, with this being the fourth report in the series (see Appendix G). Having documented the factors associated with crash occurrence and serious injury (see *ECIS Report 3*), this *Report* identifies measures to address each factor.

1.2 CONCEPTUAL APPROACH: LINKING CONTRIBUTING FACTORS TO COUNTERMEASURES

A detailed exposition of the conceptual approach to linking factors associated with crash occurrence and injury severity was provided in *ECIS Report 3*. This built on the work presented in *ECIS Reports 1 and 2*. The reader is referred to these reports for comprehensive detail of the study and the approach adopted here.

For the purposes of brevity, key points are highlighted below.

Following considerable development work, and with reference to past studies including the early work of Haddon,[21,22,23,24,25] a modified *Integrated Safety Chain* (ISC) was developed for use in the ECIS program. This followed the approach and model first outlined by Tingvall[26,27] (see *ECIS Report 3*, Figure 1.3), with additional insights taken from Cameron's *Road Trauma Chain* and other crash analysis approaches. The development work of other researchers based in Sweden is recognised.[28,29,30,31,32,33]

The modified ISC is presented in Figure 1.1 with the principles associated with each phase being summarised in Table 1.1 (also see Appendix A). Consisting of 10 phases, the modified ISC integrates Tingvall's *Driving Process Model*, and following the work of Rizzi,[32] adds post-crash response and re-integration into everyday life as distinct phases. Data capture using on-board vehicle systems was added as Phase 10. The modified ISC represents the complete crash sequence for the injured driver.

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20 Enrolment of injured drivers at The Alfred Hospital commenced in August 2014 at in June 2016 at the Royal Melbourne Hospital in June 2016. The ECIS study ceased enrolment of injured drivers in early December 2016. Full details of the ECIS method, study inclusion and exclusion criteria, enrolment rates and sample representativeness can be found in ECIS Report 1.
21 Haddon W Jr. The changing approach to the epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based. American Journal of Public Health. 1968;58(8):1431-38.
22 Peden M, Scurfield R, Sleet D, Mohan D, Hyder AA, Jarawan E, et al. (Eds.). World Report on road traffic injury prevention. Geneva: World Health Organisation; 2004.
23 Haddon W Jr. A logical framework for categorizing highway safety phenomena and activity. Journal of Trauma. 1972;12(3):193-207.
24 Haddon W Jr. Advances in the epidemiology of injuries as a basis for public policy. Public Health Reports. 1980; 95:411–421.
25 Haddon W Jr. On the escape of tigers: an ecologic note. American Journal of Public Health. 1970;60(12):2229-2234.
26 Tingvall C. Distraction from the view of governmental policy making subsection of the chapter: Government and Industry Perspectives on Driver Distraction. In: Regan M, Lee J, Young K, editors. Driver distraction: Theory, effects, and mitigation. Melbourne: CRC Press; 2008.
27 Lie A. Managing traffic safety: an approach to the evaluation of new vehicle systems. Stockholm, Sweden: Karolinska Institute; 2012.
28 Sunnevång C. Characteristics of nearside car crashes – an integrated approach to side impact safety. Umeå, Sweden: Umeå University 2016.
29 Lie A. Managing traffic safety: an approach to the evaluation of new vehicle systems. Stockholm, Sweden: Karolinska Institute; 2012.
30 Strandroth J, Sternlund S, Tingvall C, Johansson R, Rizzi M, Kullgren A. A new method to evaluate future impact of vehicle safety technology in Sweden. Stapp Car Crash Journal. 2012; 56:497-509.
31 Stigson H. A safe road transport system – Factors influencing injury outcome for car occupants. PhD thesis. Karolinska Institute: Stockholm; 2009.
32 Rizzi M, Strandroth J, Tingvall C. The effectiveness of antilock brake systems on motorcycles in reducing real-life crashes and injuries. Traffic Injury Prevention. 2009;10(5):479-87.
33 Tingvall C. The next big leap: Integrating the principles of Vision Zero within the sustainable development agenda. TAC-MUARC Road Safety Symposium. RACV Club: Melbourne; 2016.

As seen in Figure 1.1, Tingvall's ISC commences with *Normal Driving*. Other authors have used the terms 'baseline, routine, and uneventful driving',[34,35,36] 'benign and uneventful driving',[37] and 'safe driving'[38,39,40] for this phase of driving. *Normal Driving* represents the non-conflict phase of driving and is where drivers spend most of their time.[41] Ideally, a driver would spend the entirety of their trip in this phase. Doing so would result in the completion of a trip without conflict or incident. The ISC explicitly recognises, however, that deviations from *Normal Driving* occur. Whether the shift from *Normal Driving* results in a crash-relevant conflict, a near-crash event, or an actual crash[42] depends on the success or otherwise of countermeasures designed to return the driver back to *Normal Driving*.

The principle of the ISC is that any shift from *Normal Driving* towards a conflict situation is corrected. These shifts can occur due to performance failures (e.g., error, unsafe manoeuvre, driving adverse to conditions; inattention), health and driver state factors, and intentionally or unintentionally engaging in non-compliant behaviours.

The definition of *Normal Driving* is therefore vital. As outlined in *ECIS Report 3*, *Normal driving* is characterised by:

1. The control of the vehicle by a driver in a manner that is responsive to the road environment, surrounding traffic and associated traffic flow, and other road users. *Normal Driving* includes being responsive to any potential threat posed, including that posed by another road user. *Normal driving* is therefore highly contextual.

   Within the measurable bounds of *Normal Driving*, *Normal Driving* accommodates a range of driving styles and preferences ranging from conservative through to that regarded as risky driving (see *ECIS Report 3* for explanation).

2. Compliance with all traffic laws, inclusive of compliance with and/or responding appropriately to traffic signs/signals (i.e., traffic lights) including advisory signs.

The exercise of *Normal Driving* by drivers has a number of influences. Vehicle technology and infrastructure design can play an important role in supporting the driver remaining within the bounds of *Normal Driving*.

This characterisation of *Normal Driving* recognises that *Threats to Normal Driving* can exist prior to the commencement of the trip. These *threats* can relate to the driver, the vehicle, and/or to the road and road infrastructure and must also be managed.

The exercise of *Normal Driving* requires specific compliance and performance criteria, or prerequisites, to be met. Following Tingvall, these prerequisites include: seat belt use; driving within the speed limit; non-use (handling) of a mobile phone; having a BAC within the permissible limit for the licence class of the driver; non-use of illicit drugs or abuse/non prescribed use of benzodiazepines and/or opioid-based analgesics; no excessive drowsiness (see Table 1.1).

Meeting these prerequisites and managing the threats and deviations to *Normal Driving* is the basis of successfully completing a trip. Tingvall[43] stated that the role of these prerequisites was to act as the design boundary of the road transport system, noting the challenges associated with operating a system to tolerate

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34 *Normal Driving* has previously not been well defined however has been labelled baseline, routine, uneventful, typical, ordinary; see: Papazikou E, Quddus M A. Thomas, P. Detecting deviation from normal driving using SHRP2 NDS data. 96th Annual Meeting of the Transportation Research Board (TRB), Washington D.C., US, 8th-12th January 2017.

35 Klauer SG, Dingus TA, Neale VL, Sudweeks JD, Ramsey DJ. The impact of driver inattention on near-crash/crash risk: an analysis using the 100-car naturalistic driving study data (Report No. DOT HS 810 594). Washington, DC: U.S. Department of Transportation; 2006.

36 Olson RL, Hanowski RJ, Hickman JS, Bocanegra J. Driver distraction in commercial vehicle operations (Report No. FMCSA-RRR-09-042). Washington, DC: U.S. Department of Transportation; 2009.

37 Kanianthra, J. Re-inventing safety: Do technologies offer opportunities for meeting future safety needs? SAE Technical Paper 2006-21-0009; 2006.

38 Sunnevång C. Characteristics of nearside car crashes – an integrated approach to side impact safety. Umeå, Sweden: Umeå University 2016.

39 The Report authors view *Safe Driving* to be an outcome of the exercise of *Normal Driving*.

40 From 2026, EuroNCAP and ANCAP assessment protocols will be defined to reflect four distinct phases of a potential collision and crash, these being: Safe Driving; Crash Avoidance; Crash Protection; Post-Crash Safety. see: EuroNCAP. Euro NCAP Vision 2030: a Safer Future for Mobility. Leuven, Belgium: EuroNCAP; 2022. This is consistent with the characterisation of the driving process of the *Integrated Safety Chain* (ISC) adopted in this Report.

41 Eugensson A, Ivarsson J, Lie A, Tingvall C. Cars are driven on roads, joint visions and modern technologies stress the need for co-operation. 22nd Enhanced Safety of Vehicles (ESV) Conference (ESV 2011); 13-16 June 2011, Washington, DC, USA. Paper Number 11-0352.

42 A crash-related conflict, a near-crash event, and a crash are sub-types of Safety Critical Events (SCE); see Glossary and Abbreviations of this Report.

43 Tingvall C. Distraction from the view of governmental policy making subsection of the chapter: Government and Industry Perspectives on Driver Distraction. In: Regan M, Lee J, Young K, editors. Driver distraction: Theory, effects, and mitigation. Melbourne: CRC Press; 2008.

extreme behaviours. These prerequisites therefore represent the minimum expectations of the driver, and where once met, drivers can reasonably expect to be protected against injury in the event of a crash.

Tingvall identified three distinct phases where opportunities to return the driver to a state of *Normal Driving* exist, the first being a *Deviation from Normal Driving (Phase 3)*.[44,45] If the *deviation* is not corrected, the conflict situation for the driver/vehicle escalates to one of an *Emerging Situation* (Phase 4) and then to a *Critical Situation* (Phase 5*)*. The threat level to the driver and hence intervention urgency increases at each successive phase. By supporting the driver through vehicle technologies and/or infrastructure-based interventions, or by actively intervening to return to *Normal Driving,* a crash can be prevented. Failure to successfully address the *Critical Situation* (Phase 5) results in a crash becoming *Inevitable* (Phase 6). The measures to promote *Normal Driving* are primarily focussed on crash prevention. Once the crash occurs (Phase 7) the focus shifts toward the mitigation of injury. Safety countermeasures designed to manage or reduce the level of energy of the crash are integral to this goal.

Post-crash, the survival and recovery of the injured driver is dependent upon the provision of emergency and acute care (Phase 8). Supportive care following discharge from hospital and services to assist the injured driver to return home and resume their pre-crash way of life complete the chain (Phase 9).

The ISC was adopted for use in the ECIS program as it provides a systematic way to understand the crash sequence and where specific crash occurrence and injury severity factors exert their influence (see *ECIS Report 3*). This provides the basis for understanding when and how to intervene, and the relevance of specific crash prevention and/or injury mitigation countermeasures. Application of the ISC using the ECIS data is described in Chapter 2, *Method.*

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44 Tingvall (2008) refers to aiding a driver to return to *Normal Driving* when they deviate 'from a safe driving mode' (p.607); the use of the word *safe* is an important point of terminology. Tingvall C. Distraction from the view of governmental policy making subsection of the chapter: Government and Industry Perspectives on Driver Distraction. In: Regan M, Lee J, Young K, editors. Driver distraction: Theory, effects, and mitigation. Melbourne: CRC Press; 2008.

45 Infrastructure-based safety countermeasures that primarily serve to manage crash energy can also play a role in maintaining *Normal Driving*.

TABLE 1.1 PRINCIPLES OF THE INTEGRATED SAFETY CHAIN

Phase	ISC Phase	Aspects
Pre-driving (pre-trip)	*Threats to Normal Driving*	• Human, vehicle, infrastructure/environment factors that influence the ability to engage in *Normal Driving*. Includes regulations and systems concerning access to the road transport system; mode choice; educational, social, and economic factors; safety culture and enforcement; vehicle and road design regulations and practices. • Interventions are relevant prior to the commencement of a trip and serve to facilitate the conduct of *Normal Driving.* The goal is to eliminate the presence or manage the influence of these threats.
Driving (in-trip)	*Normal Driving*	• The control of the vehicle by a driver in a manner that is responsive to the road environment, surrounding traffic and other road users. *Normal Driving* includes compliance with traffic laws. *Normal Driving* can also be referred to as routine driving. • Ideally, a driver would spend the entirety of their trip in this phase. Doing so would result in the completion of a trip without conflict or incident. • The ISC explicitly recognises that deviations from *Normal Driving* occur. These shifts occur due to performance failures (e.g., error, unsafe manoeuvres, driving adverse to conditions; inattention), health and driver state factors, and/or intentional/unintentional non-compliant behaviours. • Prerequisites of *Normal Driving*: seat belt being worn; driving within the speed limit; non-use (handling) of a mobile phone; BAC within limit for licence class; non-use of illicit drugs or abuse/non prescribed use of benzodiazepines and/or opioid-based analgesic; no excessive drowsiness. These represent base design criteria for the road transport system.
	Deviation from Normal Driving	• Driver-based factors that result in a departure from the definition of *Normal Driving*, including the failure to meet the prerequisites of *Normal Driving.* • Countermeasures promote and support a return to *Normal Driving* by providing information and warnings to the driver.
	Emerging situation	• Due to the failure to correct the *Deviation from Normal Driving*, a likely vehicle-to-vehicle/road user/object conflict begins to emerge (e.g., drive too close/gap failure; drift; a sudden event occurs). Failure to correct results in escalation to a *Critical Situation*. • Countermeasures warn and promote direct and immediate intervention in the driving task to ensure a return to *Normal Driving*.
	Critical situation	• Escalation towards an inevitable (unavoidable) crash due to loss of control or failure to respond and correct the *Emerging Situation*. Last opportunity to achieve a return to *Normal Driving.* Active intervention measures are required.
Crash	*Crash unavoidable*	• Occurs because of the failure of all previous steps to return the driver to *Normal Driving*. Time-to-collision is small making the crash inevitable and immune to intervention. • Countermeasures aim to prepare the occupant/vehicle to the impending crash by way of optimizing the effectiveness of vehicle safety measures in managing crash energy.
	Crash	• Protection of the occupant from injury is the primary consideration. • Achieved by the effective control and management of crash energy. Energy-absorbing vehicle and roadside structures are vital, as is infrastructure design in order to manage crash energy and impact types.
Post-crash	*Immediate / acute care*	• Emergency response. The emphasis is initially on stabilization, extrication, and transport of the injured driver to hospital. Includes the provision of definitive trauma care as rapidly as possible to maximise survival and enhance recovery prospects. Emphasis is on systems, processes, and training to ensure an optimal outcome for the injured driver is achieved.
	Recovery	• Beyond the acute hospital, emphasis is on recovery and re-integration to pre-crash usual life.
Monitoring	*Crash Data*	• Acquisition and integration of crash data for use in crash investigation and system monitoring.

PHASE	DEFINITION AND INTERVENTION APPROACH	INTERVENTION GOAL
1. Threats to Normal Driving	• Driver (D), Vehicle (V), and Road Infrastructure/Environment (E) factors detrimental to *Normal Driving*, including factors that pre-dispose a driver to a crash or act to negatively impact driver ability to respond and avoid a crash. • D: intoxication and/or use of illicit drugs, abuse of prescribed medication; medical/health condition; experiential factors (new licence, presence of peers), offence/crash history; V: vehicle condition/roadworthiness including tyre tread and lighting systems; E: signage, road geometry, latent (in-built) risk by design. • The goal is to eliminate the presence or manage the influence of these threats.	**Measures to address human, vehicle & road environment factors detrimental to *Normal Driving***
2. Normal (Routine) Driving	• *Normal Driving* is characterised by the control of the vehicle by a driver in a manner that is responsive to the road environment, surrounding traffic and other road users such that a trip is successfully completed as planned and without conflict/incident. *Normal Driving* includes compliance with traffic laws. • Per the *Safe Driver* element of the *SRA Model of a Safe Road Transport System*[46], the prerequisites for *Normal Driving* are: seat belt worn (i.e., use of protective equipment); driving within the speed limit; non-use (handling) of mobile phone; BAC within limit for licence class; no illicit drugs used or abuse/non-prescribed use of benzodiazepines and/or opioid-based analgesics; no excessive drowsiness.	**Measures to promote and return a driver to *Normal Driving***
3. Deviation from Normal Driving	• Driver (human) factors causing a shift from *Normal Driving*. In addition to the prerequisites of *Normal Driving* not being met (excluding impairment factors present prior to the commencement of driving (Phase 1: Threats), the driver/vehicle deviates from a safe travel path due to driver performance failure(s) (e.g., error), the effect of health and driver state factors, and/or non-compliant behaviour; these factors can result in a failure to recognise roadway cues and the presence of other road users/objects resulting in an *Emerging Situation* if not corrected. • Intervention approach: provide information and support (includes warning).	
4. Emerging Situation	• Vehicle is in a position sufficiently beyond *Deviation from Normal Driving* to be a direct threat to the driver (and other road users) if left uncorrected. • Movement depends on crash type: midblock/lane departure involves a drift/deviation/move from travel lane; intersection: lack of proper response to traffic control signal and/or on-coming vehicle. • Intervention approach: warning and intervention in driving.	
5. Critical Situation	• Crash event is imminent due to non-response or ineffective response to the threat of the *Emerging Situation.* • Trajectory of vehicle: in-path of other road user, entered shoulder/off-roadway, non-response to stationary vehicle. • Intervention approach: immediate and active correction.	
6. Crash Unavoidable	• Crash is imminent with the time-to-collision (and vehicle trajectory) so short as to make the crash unavoidable. • Intervention approach: preparation for the crash with a view to controlling the level of crash energy and optimising vehicle safety systems to minimise crash energy and preparing the driver/vehicle safety systems for impact.	**Energy reduction and injury mitigation measures**
7. CRASH	• Injury mitigation through the effective control and management of crash energy. • Intervention approach: measures aimed at vehicle crashworthiness and road engineering solutions to manage impact speed, energy transfer, and energy dissipation. Includes measures to prevent secondary impacts, the prevention of vehicle rollover events and/or impacts with non-frangible roadside objects.	**Injury mitigation measures/energy dissipation**
8. Ambulance & Hospital Care	• Emphasis is on systems, processes, and training to enable an optimal outcome for the injured driver to be achieved. • Intervention approach: stabilisation, extrication and transport of the injured driver and the provision of rapid and efficacious trauma care in the hospital setting.	**Immediate post-crash emergency care, retrieval, and acute hospital trauma care**
9. Rehabilitation, Recovery, Injury/other Insurance	• Care and access to services following acute treatment for injuries. • Intervention approach: processes and programs to facilitate recovery and achievement of optimal health, function, and re-integration to everyday life post-crash and beyond the hospital setting.	**Rehabilitation, supported recovery and community integration**
10. Crash Data Systems	• Vehicle (on-board) data systems to capture critical pre-crash and in-crash data, enabling understanding of crash circumstances, occupant injury risk factors and effects of safety systems. Data collected via in-depth crash investigation. • Integrated administrative crash data, emergency service and hospital-based data systems required to monitor system performance and monitoring of road trauma. • Required for the development of road safety strategy and action plans.	**Fitment, access, collection, and reporting**

FIGURE 1.1 INTEGRATED SAFETY CHAIN USED IN THE ECIS SAFE SYSTEM FAILURE ANALYSIS

46 Stigson H. A Safe Road Transport System - Factors Influencing Injury Outcome for Car Occupants. Stockholm Sweden: Karolinska Institute; 2009. The SRA Model of a Safe Road Transport System operationalises the Vision Zero Multi-Dimensional Model for Safe Travel. 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.

1.3 REPORT OBJECTIVES

The objectives of this report are to:

1) Identify the countermeasures that will act to address the factors identified as having contributed to the occurrence of ECIS crashes.

2) Identify the countermeasures that will address factors associated with drivers being injured.

In presenting this report, reference is made to *ECIS Report 3* where the full range of factors associated with crash occurrence and injury severity were documented. The analysis presented in this report will therefore identify the proportion of serious injury crashes and specific serious injuries, where applicable, that each countermeasure will influence. The point of effect of each countermeasure in the crash sequence chain will also become clear.

1.4 INTENDED USE OF THIS REPORT

By enumerating the proportion of crashes each countermeasure is applicable to, as well as understanding the efficacy and availability of each countermeasure, the findings of this *Report* can be used to inform the development of road safety action plans. The findings will also support the development of the future vehicle regulatory agenda, the development and promotion of new technologies to address key road safety problems, as well as innovations in caring for injured road users.

The data presented in this *Report* is based on a sample of hospitalised drivers admitted to a major trauma centre in Victoria, Australia. The findings are most applicable to drivers of passenger vehicles and are not necessarily applicable to front seat or rear seat occupants. This must be considered when interpreting and applying the findings of this study.

Further, to the best of the authors' knowledge this *Report* identifies all available countermeasures applicable to these serious injury crashes and associated injuries. An assessment was also made as to the efficacy of each countermeasure and its likely availability time horizon based on existing research and author expertise.

The applicability of each countermeasure was assessed for each crash using a case-by-case analysis approach. This assessment was made on the basis of the purpose and function of each countermeasure, and with knowledge of all circumstances of each crash.

In conducting this analysis, the authors acknowledge that any policy considerations and implementation of the identified countermeasures rest with the relevant government agencies. The data is provided here to inform this process.

1.5 REPORT STRUCTURE

Following the *Introduction,* the *Method* (Chapter 2) briefly outlines the analysis approach and provides notes to aid interpretation of the results and the data tables. The results are presented over a series of six chapters in a manner consistent with the phases of the ISC and the three crash types reported throughout the ECIS program, these being Lane Departure crashes, Across Path crashes and Rear Impact crashes. Key findings are presented in the *Discussion*.

A graphical representation of the report structure can be seen in Figure 1.2.

1.6 ETHICS AND DATA ACCESS APPROVALS

The conduct of the ECIS Case Study was approved by The Alfred Hospital Research Ethics Committee (HREC, Project: 249-14), The Royal Melbourne Hospital HREC (Project: 249-14), and the Monash University HREC (CF14/2329-2014001254).

The conduct of the ECIS Control study was approved by the Monash University HREC (CF14/1930-2014000983).

Phase 1	Measures to manage threats to safe driving	**Chapter 3** 3.1 Managing driver-related threats to safe driving 3.2 Managing vehicle-related threats to safe driving 3.3 Managing road and road-infrastructure-related threats to safe driving
Phase 2	Safe driving	Safe Driver requirements: addressed by managing threats to safe driving and measures to manage deviations-emerging-critical situations
Phase 3, 4, 5	Measures to manage deviations from safe driving through to critical situations	**Chapter 4** 4.1 Measures common to all crash types 4.2 Measures specific to Lane Departure crashes 4.3 Measures specific to Across Path crashes 4.4 Measures specific to Rear Impact crashes
Phase 6, 7	Measures to manage crash energy and injury severity	**Chapter 5** 5.1 Measures common to all crash types 5.1.1 Immediate pre-crash injury mitigation measures 5.1.2 Improving vehicle safety and enhancing the level of protection against injury 5.1.3 Measures to address injury risk factors specific to crash impact configuration 5.1.3.1 Addressing injury in frontal impact crashes 5.1.3.2 Addressing injury in side impact crashes 5.1.3.3 Addressing injury in rear impact crashes 5.1.3.4 Addressing injury in rollover events 5.1.3.5 Addressing other impact-related injury risk factors 5.1.4 Measures to address impact speed 5.2 Measures to address injury risk factors specific to Across Path crashes 5.3 Measures to address injury risk factors specific to Lane Departure crashes 5.4 Measures to address injury risk factors specific to Rear Impact crashes
Phase 8	Measures to support emergency response and acute trauma care	**Chapter 6** 6.1 Provision of emergency care, resourcing and remote locations 6.2 Vehicle technology to reduce delays in crash notification 6.3 Measures to assist the extrication of injured drivers from vehicles
Phase 9	Measures to support injured drivers through rehabilitation, recovery and other post-crash matters	**Chapter 7** 7.1 Measures focused on post-acute care and going home 7.2 Measures to support drivers injured and killed in road trauma and their families 7.2.1 Supporting in event of loss of life 7.2.2 Supporting mental health and recovery 7.2.3 Supporting physical health and recovery 7.3 Measures to support access to TAC (no-fault) services 7.4 Measures to support processes associated with insurance, licensing and resumption of driving
Phase 10	Measures to facilitate crash data collection and reporting	**Chapter 8** 8.1 Data Systems 8.2 In-vehicle crash data capture technology

FIGURE 1.2 REPORT OUTLINE WITH LINK BETWEEN THE ISC AND CHAPTERS SHOWN

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2 METHOD

The structure of the ECIS program, data collection methods, concepts underpinning *Vision Zero* and the *Safe System approach,* and driver crash and injury characteristics were described in detail in *ECIS Report 1*, while the *ECIS Report 2* examined the critical role of speed. The *ECIS Report 3* provided a detailed exposition of crash occurrence and injury severity contributing factors across the ISC. Collectively, these *Reports* provided a large number of findings regarding the nature, influence, and incidence of factors associated with crashes and injury severity.

Of particular note, the findings presented in *ECIS Report 3* form the basis of the countermeasure analysis presented in this *Report*. Using an expanded form of Tingvall's modified ISC the data presented in *ECIS Report 3* identified the factors directly contributing to crashes and serious injury, and crucially, quantified their role in serious injury road trauma. Simplistically, the data presented in *ECIS Report 3* highlighted the size of the serious injury crash problem that could be addressed, at both the broad level and at the micro-level, through the application of specific countermeasures.

In reading this *Report,* the reader is strongly encouraged to read *ECIS Reports 1, 2 and 3*, in order. Doing so will enable the reader to fully understand the concepts used, how contributing factors were identified, their incidence, and how the case-by-case analysis influenced the estimations of countermeasure efficacy presented in this *Report*.

This chapter describes the countermeasure allocation approach adopted in this *Report* and provides guidance on how the findings are to be interpreted.

The ECIS program enrolled 400 injured drivers admitted to *The Alfred Hospital* or the *Royal Melbourne Hospital* for treatment sustained in a road crash. Of these 400 drivers, 47% (n = 188 of 400) sustained MAIS 3+ severity injuries. The analysis of these crashes and the injuries sustained by these drivers form the basis of this *Report*.

Three principal crash types were identified: Lane Departure crashes; Across Path (intersection) crashes, and Rear Impact crashes; crash sub-types were also defined (see Appendix B). The findings of this *Report* are presented in a manner consistent with these crash types.

2.1 IDENTIFYING MEASURES TO ADDRESS ROAD TRAUMA: OPERATIONALISING THE INTEGRATED SAFETY CHAIN (ISC) USING IN-DEPTH ECIS CRASH DATA

2.1.1 Establishing a countermeasure library for application in serious injury crashes

As described in the *Introduction,* the ECIS program was established to provide a comprehensive understanding of the causes and consequences of a sample of drivers injured in hospitalisation-severity crashes. By presenting the factors associated with crash occurrence and injury in the context of the ISC crash sequence model – as shown in *ECIS Report 3* - the progressive nature of crashes and the accumulation of factors associated with their occurrence can be seen. This analysis also highlighted the point of effect of each contributing factor in the crash sequence.

Using the findings of *ECIS Report 3* as an input, this *Report* provides a detailed analysis of countermeasures that can act to eliminate, or mitigate, the influence of factors found to have contributed to the occurrence of crashes and to driver injury severity. Due to the linkage between the contributing factor and the countermeasure, the position of the countermeasure in the crash chain reflects its mechanism of action within the ISC framework

As a point of terminology, the term 'factors' is used interchangeably with 'risk factors' to describe contributing factors in this *Report*.

To meet the project objective of identifying crash prevention and injury prevention measures, a process of systematically linking countermeasures to all observed contributing factors was undertaken (see Appendix A for general heuristics). This relied on a detailed understanding of the purpose and function of each countermeasure. This task was accomplished with input from a range of experts throughout the ECIS program but in particular, through the ECIS Safe Systems I and ECIS Safe Systems II Workshops (see *ECIS Report 3*).

In addition to the Expert Group, extensive reference was made to the research literature (for example [47,48,49], among others), vehicle regulations and related vehicle safety protocols (including NCAP Test Protocols and relevant technology roadmaps), road design manuals (e.g., Austroads Guide to Road Design[50]; US DOT Federal Highway Administration Highway Design Library[51]) and other specialist industry publications to identify relevant countermeasures. Reference was also made to the US Patent Office to understand emerging vehicle technology (https://www.uspto.gov/). The ECIS crash data was also used to identify several countermeasure opportunities that are not presently available.

This process resulted in the establishment of a library of 278 countermeasures, each linked to a specific crash causation or injury severity factor, each positioned within the modified ISC. This library formed the basis of the purpose-built *ECIS Safe System Decision Support Tool (ECIS-DST)* which was used in the production of this *Report*. The ECIS-DST was operationalised in MS Excel and incorporated data for each ECIS crash that is stored in SPSS. This relied on a case-by-case analysis of the data and involved an examination of each identified contributing factor and the linked countermeasure. The ECIS-DST enabled the aggregation of data that linked the number and percent of crashes/drivers where a contributing factor was evident, as well as number of crashes/drivers where each countermeasure was applicable; that is, the number of drivers/crashes sensitive to a countermeasure (see Section 2.1.2 below).

Countermeasure efficacy ratings were also included for each identified countermeasure, as was the categorisation of countermeasures using the coding scheme presented in Table 2.1 (below).

For completeness, it is noted here that the ECIS case-level (driver-crash) data is held in an SPSS database that consists of 3470 variables. This includes a variable for each identified contributing factor, with these variables structured following phases of the modified ISC. Countermeasures relevant to each contributing factor are included in the SPSS data.

2.1.2 Identifying crashes ‘sensitive’ to countermeasures

Having established the risk factor/countermeasure library, the applicability of each countermeasure was examined for each crash. Whether the crash was ‘sensitive’ to the countermeasure was based on the function and technical performance specifications of the countermeasure being considered. This included whether the effect of the countermeasure was conditional on the presence or absence of other driver, vehicle, or road infrastructure characteristics, resulting in a smaller subset of relevant crashes. Impact speed and the nature and severity of injuries sustained was also considered. Combined, these parameters define ‘field of influence’ of each countermeasure. This process is critical to ensuring that the countermeasure linked to the contributing factor is directly applicable to the crash.

The terms, *sensitive* and *applicable* are routinely used when understanding the relationship of countermeasures to a crash, and vice versa. For clarity, the following distinction is made:

- Based on the presence of a contributing (risk factor) and the function of a countermeasure (i.e., field of influence), a crash can be considered to be *sensitive* to that countermeasure.
- Based on the function of a countermeasure (i.e., field of influence) and the presence of a contributing (risk factor), a countermeasure can be considered to be *applicable* to a crash.

While this terminology is routinely used in the assessment of vehicle safety technology, its application to a broader range of countermeasures is novel.

2.1.3 Countermeasure categories

Categories based on the intended focus and action of the countermeasure were developed (Table 2.1). The intention was to provide a point of distinction between countermeasures by their mechanism of action. These categories are also of value when used in conjunction with the *Safe Driver, Safe Vehicle and Safe Road* elements of the road transport system.

For instance, a countermeasure may relate to the vehicle, but the mechanism of action is driver focussed; an example of this is an advisory headway monitoring system fitted to the vehicle *(i.e., Safe Vehicle)* but the countermeasure is driver-focussed (i.e., H-6). These categories permit this distinction to be made.

47 Elvik R, Vaa T, Hoye A, Sorenson M. The Handbook of Road Safety Measures: Second Edition. UK: Emerald Publishing Limited; 2009.
48 Shinar D. Traffic Safety and Human Behavior: Second Edition. UK: Emerald Publishing Limited; 2017.
49 Truong J, Strandroth J, Logan DB, Job RFS, Newstead S. Utilising human crash tolerance to design an interim and ultimate safe system for road safety. Sustainability. 2022 Mar;14(6). 3491.
50 https://austroads.com.au/safety-and-design/road-design/guide-to-road-design
51 https://highways.dot.gov/federal-lands/design/library

A distinction is also made between elements of the post-crash response, with measures focussed on immediate emergency response and acute care separated from measures to support the medium-to-longer term recovery needs of injured drivers.

Where applicable, an 'S' is used within the results tables to denote measures that relate to speed management, in addition to the *Safe System Element (SSE)*. This is consistent with the conceptual approach that speed – whether it be travel speed or impact speed – is embedded with the *Safe Driver, Safe Vehicle, and Safe Roads* elements of the road transport system.

TABLE 2.1 COUNTERMEASURE CATEGORIES AND THEIR FOCUS

Countermeasure category	Countermeasure focus
Driver-focussed (human)	
H-0	Information, advice, requirements relating to person-based risk factors outside of the vehicle (prior to specific journey where crash occurred), or that address 'exposure' (driving, time-of-driving).
H-1	Behavioural focussed health/GP/learning information support, intervention, and management.
H-2	Requirements relating to driver licensing and training.
H-3	Interventions involving enforcement / police activity to address risk factors, as they apply to road laws and regulations only.
H-4	In-vehicle technological solutions to address driver risk factors prior to driving.
H-5	In-vehicle technological solutions to ensure driver compliance with current regulations and laws.
H-6	In-vehicle technological driver assistance systems to ensure or return to *Normal Driving*
Vehicle	
V-1	Interventions specific to passive safety of vehicle(s), including mass-ratio, geometry, star rating, airbags.
V-2	Active safety (technology) – not those in H-4 or H-5 or H-6.
V-3	Event Data Recorder (EDR).
Road infrastructure	
R	Any infrastructure / road intervention (excluding speed limit reduction).
Post-crash	
P-EA	Measures focussed on enabling optimal post-crash ambulance and acute hospital care (trauma centre).
P-RID	Measures focussed on enabling and supporting optimal post-crash rehabilitation, insurance, compensation services and driving-related matters.
Speed management	
S	Measures relating to speed management, including speed limit reduction.

2.1.4 Countermeasure efficacy

In establishing the countermeasure library, each countermeasure was assessed for its likely efficacy in addressing the contributing factor given. A scale of *low* (<20%), *medium* (20% - 50%), and *high* (50%+) was adopted. This assessment was based on a number of parameters, including its function and technical limits (i.e., operational boundaries), effectiveness studies published in the research literature and technical reports/manuals, as well as expert opinion. For countermeasures not presently available and where no formal evaluations were available, expert opinion of the ECIS Investigator was used; assessments were made in the context of relevant ECIS crashes.

To clarify, the estimated efficacy rating pertained to the likely influence of the countermeasure in addressing the defined risk factor, as seen in the ECIS case data; these do not reflect crash reduction factors per se, this being an important distinction. It is also important to bear in mind that the efficacy of each countermeasure was assessed in isolation, or independently, of the potential influence of other contributing factors.

To support the nominated efficacy ratings, detail as to the technical performance and components of countermeasures is described, as is direct supporting evidence where necessary. This is particularly relevant to the efficacy ratings for driver-focussed and vehicle technology-based countermeasures, notwithstanding the process and reference materials described in Section 2.1.1. We also note that for a number of efficacy ratings, evidence for countermeasure efficacy was derived from the findings of the ECIS program itself, as seen in *ECIS Reports 1 and 2* in particular; this was particularly relevant to the role of vehicle safety and speed.

The efficacy nominated for road infrastructure measures are generally not specified in the body of the *Report*. It was considered that the efficacy ratings for road infrastructure measures are well understood and less contested, noting that direct reference to the crash and the functional specifications of each countermeasure was used in combination with road design manuals, evaluation studies and expert consensus. The number of relevant references to support these efficacy ratings are numerous. However, we do note that technology focussed infrastructure countermeasures require real-world evaluation; nonetheless, we have confidence in the ratings assigned given our understanding of the technical specifications of the countermeasures and the case-by-case analysis of ECIS crashes.

A number of countermeasures are focussed on addressing the broader population level of drivers, as distinct from addressing observable contributing factors relevant to a subset of drivers. This is relevant only to driver-focussed countermeasures that address increased risk of future crash involvement associated with drivers having prior crash history and prior traffic offences (see *ECIS Report 3 for detail).*

As a matter of interpretation, percent values reported in each data table reflect the size of the hospitalisation crash problem that can be directly addressed by the specified countermeasure. With the direct linking of ECIS crashes to the exact functional specifications of countermeasures, the efficacy ratings used may be higher than published broad crash-based population assessments and evaluations of countermeasure efficacy.

With respect to the estimated efficacy ratings, the authors have used the best available information research evidence available and expert opinion to estimate the efficacy of each countermeasure. Notwithstanding this, it is accepted that these efficacy assessments may be contested, and we readily acknowledge that in some instances real-world evaluations of countermeasure efficacy are lacking at present; these are specified where applicable.

2.1.5 A note on countermeasure efficacy and cost-effectiveness

Countermeasure efficacy is based solely on the effect of the countermeasure in addressing the specified risk factor and its influence — whether it be in preventing a crash or mitigating injury severity — as seen in each ECIS crash.

Neither the cost-effectiveness nor policy implementation aspects (including policy translation) were considered in nominating the efficacy rating of each countermeasure.

2.1.6 Countermeasure time horizon

An availability time horizon for each countermeasure was identified. For countermeasures under development, a short-term (within 5-years) or medium-term (> 5 years) availability time horizon was estimated based on best available information.

In most instances, the capacity and knowledge to implement short-term time horizon countermeasures exists now. With respect to vehicle technologies most, if not all of the advanced functionality represents an incremental advance where functional performance is a natural progression or linking of existing technologies. For driver-focussed countermeasures, the implementation of these countermeasures is dependent on the development of relevant processes and legislation (as needed). Whether these countermeasures demonstrate the estimated level of efficacy, if implemented, will be seen in the fullness of time when the necessary evaluations are conducted.

Throughout the *Report* and the data tables, and with respect to countermeasure availability, the term 'Now' is taken to refer to countermeasures that are currently implemented. With respect to vehicle technologies and other vehicle safety measures, the use of the term 'Now' is not taken to mean all vehicles in the passenger car fleet have the countermeasure of interest, but rather the technology currently being fitted to vehicles.

2.1.7 Forward looking statements

It is accepted that some time horizon and efficacy ratings are forward-looking statements, which may vary. The determination of countermeasure efficacy ratings is, in many instances, subject to the conduct of a real-world evaluation once implemented.

2.2 NAVIGATING AND INTERPRETING THIS REPORT

2.2.1 ISC position locater bar

The findings of this work are presented in accordance with the structure of the ISC. To orient the reader, the ten (10) phase ISC colour bar shows the reader their position in the ISC (Figure 1.1). This is designed to provide the reader with a direct and easy reference point to the modified ISC. This feature is placed in the header of each page where results are presented (i.e., Chapters 3 – 8).

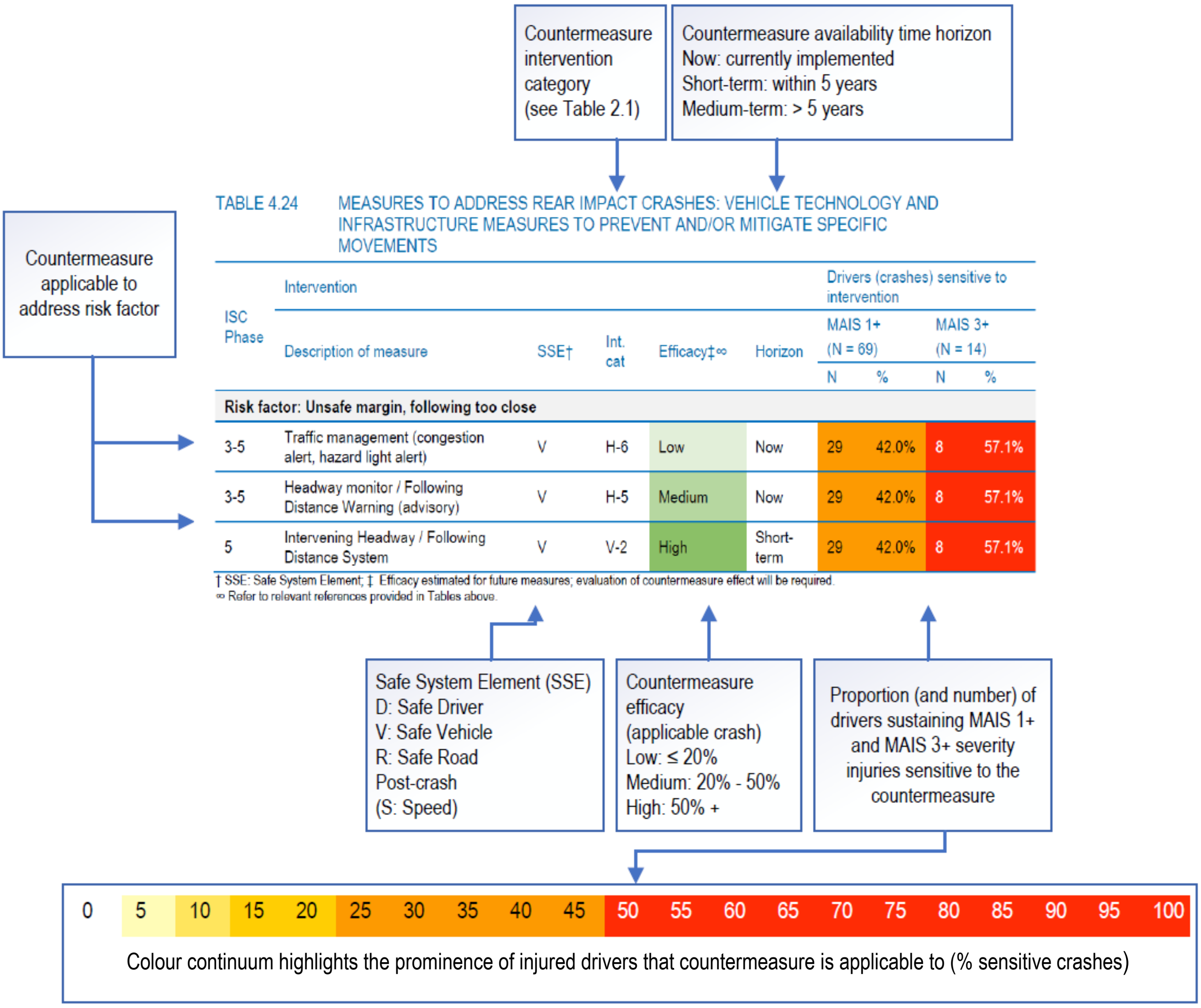
In the example provided below, contributing (risk) factors and applicable countermeasures relevant to *Deviations from Normal Driving* (Phase 3), the *Emerging Situation* phase (Phase 4), and the *Critical Situation* phase (Phase 5) are shown on that page of the *Report*.

As the reader moves through the Results chapters (Chapter 3 to Chapter 8), reference to the ISC position locator bar highlights the progression through the crash sequence.

2.2.2 Data tables and primary analysis outcome

The results are presented in a series of data tables. The features of the data tables are explained in text boxes below. The key analysis output is the proportion of injured drivers each countermeasure is applicable to. That is, percent value provided represents the size of crash problem addressed by the specified countermeasure.

This percent value, combined with the efficacy of the countermeasure can be used as the basis for prioritising the implementation of high efficacy measures that will address a high proportion of the serious injury road trauma problem.



ISC Phase	Intervention: Description of measure	SSE†	Int. cat	Efficacy‡∞	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 69) N	%	MAIS 3+ (N = 14) N	%
Risk factor: Unsafe margin, following too close									
3-5	Traffic management (congestion alert, hazard light alert)	V	H-6	Low	Now	29	42.0%	8	57.1%
3-5	Headway monitor / Following Distance Warning (advisory)	V	H-5	Medium	Now	29	42.0%	8	57.1%
5	Intervening Headway / Following Distance System	V	V-2	High	Short-term	29	42.0%	8	57.1%

† SSE: Safe System Element; ‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
∞ Refer to relevant references provided in Tables above.

2.2.3 Data analysis

The primary analysis outcome of this *Report* is the proportion of hospitalised ECIS case drivers that each countermeasure will influence. The reader should be mindful of crash/injury countermeasure sub-group analysis where percent values are high but where cell counts are small. No formal statistical analysis was performed comparing the proportion of crashes, drivers, or injuries to which a countermeasure is applicable across crash types.

3 RESULTS – MEASURES TO MANAGE *THREATS TO NORMAL DRIVING*

This chapter presents driver, vehicle and road infrastructure countermeasures aimed at addressing pre-trip factors identified as having played a contributory role in the occurrence and/or injury severity of ECIS crashes. These contributory factors, also referred to as *risk factors*, were presented in detail in *ECIS Report 3*.

Following the *ECIS* ISC, these factors represent *Threats to Normal Driving*. The identified factors act to pre-dispose a driver to being involved in a crash; negatively impact a driver's ability to control a vehicle, or negatively impact a driver's ability to respond to an emerging situation and avoid a crash. Managing these factors ensures that the pre-conditions for *Normal Driving* are met. Doing so can have further positive benefits, including that *Deviations from Normal Driving* are less likely to occur once a trip commences.

Having described the presence (i.e., number and percent of injured drivers / crashes) of each risk factor (see also *ECIS Report 3*), data pertaining to countermeasures reflects the applicability — or relevance — of that measure to address the risk factor specified. An alternative way to understand this is whether the crash (or driver injury) is 'sensitive' to a countermeasure given its function and purpose.

With consideration also given to the efficacy and time availability horizon of each countermeasure, this analysis aims to highlight countermeasures likely to provide benefit in reducing serious injury road trauma. Bearing in mind that each countermeasure is specific to the risk factor and acts in isolation from others — and given the multi-factorial nature of injury crashes — 'managing out' one risk factor alone does not necessarily guarantee elimination of the crash or mitigation of serious injury; rather, implementation of a suite of carefully selected countermeasures across the crash sequence is likely to be required given the number and extreme spread of contributing factors associated with these crashes.

With emphasis on understanding the potential contribution of countermeasures in reducing serious injury road trauma, percent values are presented as a function of 400 MAIS 1+ injured drivers and of 188 MAIS 3+ injured drivers. These percent values represent the proportion of hospitalised drivers that would obtain benefit from the specified countermeasure. In presenting this countermeasure analysis, reference is made to risk factors where appropriate for context, as are any differences across the three defined crash types. For a full presentation of risk factors by crash type and injury severity, the reader is referred to *ECIS Report 3*.

The chapter commences with a presentation of measures to address driver-related *Threats to Normal Driving*, following by vehicle-related threats, and road and road infrastructure threats to *Normal Driving*. Given the number of risk factors and associated countermeasures, measures are briefly described with full information available in the data tables.

3.1 MANAGING DRIVER-RELATED *THREATS TO NORMAL DRIVING*

Driver-related *Threats to Normal Driving* were divided into seven categories, each consisting of several individual threats (see *ECIS Report 3*, Table 3.1.1). The countermeasures associated with each of these threats is discussed below.

3.1.1 Measures to address driver experiential risk factors

Driver experience, as evidenced by vehicle control and behaviour was evident in the crash of 8.0% of ECIS case drivers (n = 32 of 400); these crashes were predominantly Lane Departure crashes (n = 24, 75.0% of 32) with a small number being Across Path crashes (n = 5, 15.6% of 32). Related to this, a driver aged under 25 years of age with a peer passenger present was also apparent as a risk factor (3.8%, n = 15 of 400; LD: n = 8; AP: n = 7).[52]

Population-based countermeasures to address these risk factors in the relevant driver cohorts relate to extension of Graduated Driver Licence (GDL) requirements, either through more specific requirements (i.e., increased night-time hours; added road surface experience requirement) or by potentially extending peer passenger restrictions to drivers up to and including 24 years of age. These are estimated to be medium efficacy countermeasures (see Table 3.1). Vehicle-based technology, including telematics and the use of 'smart-key' (or smart-licence) driver identification technology were also identified to address specific risk factors associated with driver experiential factors.

The effect of having limited experience of driving in Australia was seen in 0.8% of crashes (n = 3 of 400), as evidenced by driver-vehicle decision making and vehicle movements. Noting the relatively small proportion of

52 As shown in ECIS Report 1, there were 73 (18.3%, of 400) crash-involved drivers aged under 25 enrolled to the ECIS program (Learner permit: n = 1; Probationary (P1/P2) licence: n = 43). In total, 121 crashes (30.2%, of 400 injured drivers) involved a driver aged under 25 years.

the crash problem to be addressed, driver-focussed education supplemented with licence history requirements (i.e., violation, crash free period) was identified as a potential, albeit low efficacy, countermeasure.

TABLE 3.1 MEASURES TO ADDRESS DRIVER EXPERIENCE *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat.	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Inexperience driving in Australia: Recent overseas visitor, including short-term visa holder									
1	Direct (compulsory) provision of information on driving in Victoria (printed matter/digital); Addition of enhanced requirements regarding licence validation and driving history on arrival / entry[a]	D	H-0	Low	Now	3	0.8%	3	1.6%
Risk factor: Lack of experience, evidenced by vehicle control and behaviours (includes drivers on probationary permit, irrespective of age if first licenced for passenger vehicle, not applicable for motorcycle licence)									
	Enhanced Graduated Driver Licence (GDL) / Graduated Licensing System requirements#								
1	Increase number of night-time hours [b]	D	H-2	Medium	Now	9	2.3%	4	2.1%
1	Add road surface experience requirements [c]	D	H-2	Medium	Now	6	1.5%	3	1.6%
	Vehicle-based technology								
1	Telematics fitment and on-going monitoring as licensing requirement[d]	V, S	H-4	Medium‡	Short-term	32	8.0%	15	8.0%
1	Vehicle ignition technology (e.g., smart key)[e]	V, S	H-4	Medium‡	Short-term	32	8.0%	15	8.0%
1	Vehicle ignition technology to address use overpowered vehicle[f]	V, S	H-4	Medium‡	Short-term	1	0.3%	0	0.0%
Risk factor: Driver under 25 years with a peer passenger present (+/- 3 years driver age)									
1	Enforce P1 licence requirement regarding passenger restriction[g]	D	H-3	Medium	In use (enhance)	7	1.8%	3	1.6%
1	GDL: extend passenger restriction to drivers <25 years of age[h]	D	H-2	Medium	Now	8	2.0%	3	1.6%

Extensive evidence exists for the safety benefit of GLS. ‡ Efficacy assessments estimated for future measures; population-based evaluation required.

Notes (defining 'sensitive crashes'): a. No formal evaluation on effect however for other outlined and discussion of a range of countermeasure options, see: Wilks J, Watson B, Faulks IJ. International tourists and road safety in Australia: developing a national research and management programme. Tourism Management. 1999;20(5):645-54.

b. Currently 20 hours – increased hour requirement conceptually of benefit, though requires quantification; size of crash problem to be addressed is based on experiential factor + crash occurred at night seen in ECIS.

c. Sensitive crashes: experiential factors plus road surface condition (i.e., unsealed, wet) as contributing factors; countermeasure involves a requirement for hours driving on unsealed and/or wet road surfaces as a GDL training requirement. Based on the principle that gaining experience on different road surface conditions where novice drivers at higher risk of crash involvement may translate into a safety benefit, requires evaluation for effect and optimal number of hours on different surfaces.

d./ e./ f. Sensitive crashes: crashes where driver experiential factor was a contributing factor for crash. Measure relevant to probationary drivers.

d. Expected efficacy is based on a telematics requirement embedded into the licensing process inclusive of on-going monitoring with appropriate penalties and/or extension of probationary licence / GLS period; requires further technology enhancements including fitment into vehicles as standard equipment and ability to retrofit appropriate telematics drives into vehicles, inclusive of integration into licensing system; population-based evaluation is required.to assess estimate benefit.

e./f. Vehicle ignition technology to depower vehicle based on driver (current exemplar systems: Ford MyKey); population-evaluation required, however expected medium efficacy due to the active intervention in limiting the vehicle speed and other functions; integration with the licensing system required.

f. Sensitive crashes: inappropriate use of overpowered vehicle in crash with observable driving behaviour related to exceeding speed limit.

g. Sensitive crashes: Held P1 licence with peer passenger present (no exception permitted).

h. Sensitive crashes: Driver under 25 with peer present, inattention in crash.

g. / h. Extend elements of GLS requirements to all drivers under 25 years of age.

3.1.2 Measures to address licensing and vehicle registration related risk factors

Unlicensed drivers (5.0%, n = 20 of 400), driving an unregistered vehicle (1.5%, n = 6 of 400) and driving unsupervised as a learner driver (0.8%, n = 3 of 400) were present in a small number of crashes. Enforcement-based approaches, supported by using Automated Number Plate Recognition (ANPR) systems, were identified as having medium efficacy to address this risk factor (Table 3.2).

Broader education on supervised driving requirements was also identified for the 0.8% of crash-involved drivers. This was classified as a low efficacy intervention given the nature of the drivers involved and the current use of public education programs to support enforcement-based countermeasures.

TABLE 3.2 MEASURES TO ADDRESS DRIVER LICENSING CONDITION AND VEHICLE REGISTRATION *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat.	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Unsupervised learner driver[a]									
1	Education on supervised driving requirements	D	H-2	Low	Now	3	0.8%	1	0.5%
1	Vehicle ignition technology (e.g., smart-key, smart-licence)[b]	V	H-4	Low to Medium‡	Short-to-medium term	3	0.8%	1	0.5%
1	Enforcement (via ANPR: registered same address of, or vehicle registered to known learner)[b]	D	H-3	Medium	Now	3	0.8%	1	0.5%
Risk factor: Unlicensed driver (suspended, disqualified)									
1	Enforcement (including through broad use of ANPR)[c]	D	H-3	Medium	Now	20	5.0%	10	5.3%
Risk factor: Unregistered vehicle									
1	Enforcement (including through broad use of ANPR)[c]	D	H-3	Medium	Now	6	1.5%	3	1.6%

‡ Efficacy assessments estimated for future measures; evaluation of countermeasure effect among relevant cohorts will be required.

a. Measures relevant to learner drivers.

b. Vehicle ignition technology to depower vehicle based on driver (current exemplar systems: Ford MyKey); population-evaluation required. Despite the active intervention in limiting the vehicle speed and other functions, anticipated use of the key/licensed based interlock among this unlicensed cohort likely to be low, hence attributed to be a low efficacy measure. Future systems may use face recognition which would be expected to have higher efficacy, notwithstanding technology acceptability considerations.

c. Countermeasure is inclusive of sanctions (fines, impoundment, licence suspension etc..) and broad use of ANPR and detection of relevant drivers/vehicles. Outcome is prevention, detection and removal.

3.1.3 Measures to address prior crash-involvement and traffic offence-related risk factors

ECIS case drivers reported prior (5 year) involvement in an injury crash (11.0%, n = 44 of 400), non-injury property damage only (PDO) crashes (14.0%, n = 56 of 400), and traffic offences (36.0%, n = 144 of 400). Speed-related offences (24.8%, n= 99 of 400) were most common, with drivers also reporting red light violations (4.8%, n = 19 of 400), while few reported prior seat belt offences and mobile phone use offences.

A range of countermeasures to address the known future crash and traffic offence risk posed by these drivers were identified (Table 3.3A, Table 3.3B). The implementation of these measures is specific to drivers meeting the relevant criteria as a means to mitigate future crash-involvement risk.

Technology-based monitoring solutions, specifically intervening Intelligent Speed Adaption (ISA) fitted to vehicles of drivers who were previously detected speeding, represents a high-value measure by acting to mitigate the future crash involvement risk — and the related increased risk of serious injury — for these drivers (Table 3.3B).

Medium efficacy behavioural-based measures include passenger restrictions for drivers having had a crash with a passenger in the vehicle, and risk-based managed stepped interventions (e.g., use of sanctions plus behavioural interventions; monitored by licensing authority) focussed on addressing risk behaviours.

Installation of vehicle telematics systems was considered to be a medium efficacy countermeasure due to fitment being a licence condition and the data being monitored by the licensing authority, as well as being a prerequisite for registration and insurance. Requirements to use a vehicle ignition 'smart-key' (or smart-licence) was also considered to be a medium efficacy intervention once available. Telematics implemented by insurers could be expected to have a lower level of efficacy than telematic-based technology implemented through the licensing authority even if routinely monitored.

Other low efficacy measures identified were behavioural interventions designed to address driver behaviour, including for instance drivers receiving offence-crash specific letters from police and/or the licensing agency.

TABLE 3.3A MEASURES TO ADDRESS DRIVER CRASH AND LICENCE OFFENCE HISTORY *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) N	MAIS 3+ (N = 188) %
Risk factor: Crash history - involved in injury crash in past 5-years (ECIS Case [A] driver) †									
1	Passenger restriction (not age-based); (ECIS crash involved inattention and passenger present in vehicle)[a]	D	H-2	Medium	Now	8	2.0%	3	1.6%
1	Licence review given prior crash	D	H-2	Low	Now	44	11.0%	15	8.0%
1	Vehicle ignition technology (smart-key, smart-licence) / telematics	V	H-4	Medium‡	Short-term	44	11.0%	15	8.0%
1	Letter from police or road authority	D	H-3	Low	Now	44	11.0%	15	8.0%
Risk factor: Crash history - involved in a non-injury property damage only (PDO) crash within last 12-months (ECIS Case [A] driver) †									
1	Insurers refer to licence review[b]	D	H-2	Low	Now	56	14.0%	23	12.2%
1	Insurer implemented telematics[c]	V	H-4	Low to Medium‡	Now	56	14.0%	23	12.2%

† See ECIS Report 3 for references on the relationship between past crashes and traffic offences and future crash involvement.
‡ Efficacy assessments estimated for future measures; population-based evaluation required, with the exception of intervening ISA as seen to have high efficacy in preventing speed episodes.
Note (defining 'sensitive crashes'):
a. Irrespective of driver age includes prior crash with inattention as a factor, passenger present and not already subject to GDL passenger restrictions).
b. Insurer to refer non-injury / property-damage only (PDO) crashes as police reported crashes referred by police and/or crash known to licensing authority through data systems.
c. Insurers have less tools available than licensing authorities to manage driving risks that may be observable through telematics data. Trials underway.

TABLE 3.3B MEASURES TO ADDRESS DRIVER CRASH AND LICENCE OFFENCE HISTORY *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Driving history - Offence (any) within last 12-months (ECIS Case [A] driver) †									
1	Letter from police and road authority (offence specific)	D	H-3	Low	Now	144	36.0%	61	32.4%
1	Behavioural intervention (online and/or in-person)	D	H-1	Low	Now	144	36.0%	61	32.4%
1	Managed stepped intervention (offence specific & risk-based) - education to behavioural intervention (inclusive of sanctions).	D	H-1	Medium‡	Short-term	144	36.0%	61	32.4%
1	Vehicle telematics through licensing authority (and monitored).[c d]	V	H-4	Medium‡	Short-term	144	36.0%	61	32.4%
1	Vehicle ignition technology (smart-key, smart-licence) through licensing authority (and monitored).[e]	V	H-4	Medium‡	Short-term	144	36.0%	61	32.4%
Risk factor: Driving history: Offence (speed) within last 12-months (ECIS Case [A] driver) †									
1	Behavioural intervention (online and/or in-person)	D, S	H-1	Low	Now	99	24.8%	44	23.4%
1	Intelligent Speed Assist (ISA) fitment (intervening systems, retrofitted)	V, S	H-5	High	Now	99	24.8%	44	23.4%
Risk factor: Driving history - Offence (specified) within last 12-months (ECIS Case [A] driver) †									
1	Red light offence specific behavioural intervention (online and/or in-person)	D	H-1	Low	Now	19	4.8%	9	4.8%
1	Seat belt use specific behavioural intervention (online and/or in-person)	D	H-1	Low	Now	6	1.5%	4	2.1%
1	Mobile phone use specific behavioural intervention (online and/or in-person)	D	H-1	Low	Now	5	1.3%	3	1.6%

† See ECIS Report 3 for references on the relationship between past crashes and traffic offences and future crash involvement.
‡ Efficacy assessments estimated for future measures; population-based evaluation required, with the exception of intervening ISA as seen to have high efficacy in preventing speed episodes. At a general prevention sense, these countermeasures are aimed at preventing re-offending; in doing so, a crash prevention benefit could be expected.
Notes (defining 'sensitive crashes'):
a. Irrespective of driver age includes prior crash with inattention as a factor, passenger present and not already subject to GDL passenger restrictions).
b. Insurer to refer 'minor' / property-damage only (PDO) crashes as police reported crashes referred by police and/or crash known to licensing authority through data systems.
c. Insurers have less tools available than licensing authorities to manage driving risks that may be observable through telematics data.
d. Expected efficacy is based on a telematics requirement embedded into the licensing process inclusive of on-going monitoring with appropriate penalties; requires further technology enhancements including fitment into vehicles as standard equipment and ability to retrofit appropriate telematics drives into vehicles, inclusive of integration into licensing system; population-based evaluation is required.to assess estimate benefit.
e. Vehicle ignition technology to depower vehicle among other changes to vehicle systems (current exemplar systems: Ford MyKey); population-evaluation required, however expected medium efficacy due to the active intervention in limiting the vehicle speed and other functions; integration with the licensing system required.

3.1.4 Measures to address drowsy driving

While a driver being drowsy before commencing their trip is classified as a *Threat to Normal Driving*, the impact of this lack of alertness on driving performance is felt only once the trip commences, as is any further degradation in alertness as the trip continues. Drowsy driving initially results in deviations from *Normal Driving* which, if left uncorrected can result in a crash.

Pre-trip drowsy driving countermeasures were identified, as were in-trip real-time technology-based countermeasures. These countermeasures are discussed together in the next chapter (Section 4.1.4.3).

3.1.5 Measures to address factors associated with alcohol and illicit drugs

The impairing effects of alcohol and the use of illicit drugs was identified as having contributed to the occurrence of 11.3% (n = 45 of 400) and 12.8% (n = 51 of 400) of ECIS crashes respectively, with this being higher for MAIS 3+ crashes (13.8%, n = 26 of 188; 17.6%, n = 33 of 188). These factors were more prominent in Lane Departure crashes (alcohol: 17.3%, n = 35 of 188; illicit drug(s): 19.3%, n = 202) than Across Path and Rear Impact crashes (see *ECIS Report 3*, Table 3.1.1).

Given the differences in the use of alcohol and illicit drugs and the targeted nature of countermeasures these are presented separately (Table 3.4). For completeness, 4.3% (n = 17 of 400) of crashes occurred where a driver was impaired through use of both alcohol and illicit drugs; 7.0% (n = 28 of 400) of crashes involved a driver where alcohol alone was a contributing factor; and 8.5% (n = 34 of 400) occurred where a driver had used an illicit drug and its use was a contributing factor to the crash. Hence, alcohol and/or illicit drugs played a contributing role in 19.8% (n = 79 of 400) of crashes (see *ECIS Report 3* for detail).

This sizeable proportion of crashes are identified as being 'sensitive' to countermeasures specifically designed to counter driving with an illegal BAC or having used illicit drugs.

With both factors representing *Threats to Normal Driving*, their harmful effects on *Normal Driving* persist through the pre-crash chain. There are a range of countermeasures, each with a different degree of efficacy with the potential to mitigate or prevent these crash events entirely (Table 3.4). Select technology-based solutions listed are expected to have high efficacy once they become available. Identified countermeasures to address drink-driving (and drug-driving with specific modifications) were as follows:

- High efficacy
  - Enforcement (breath-test: generalised, site specific), supplemented with public education.
  - Enforcement sanctions (e.g., at roadside, impoundment, licence suspension).
  - Active (manual) alcohol interlock (intervening) fitted as standard equipment to vehicles.
  - Passive alcohol sensor plus interlock (intervening), fitted as standard equipment to vehicles.
  - Enforcement - sanction – rehabilitation therapeutic justice pathway model: integrated risk-based sanction and behavioural intervention (inclusive of therapeutic management) multi-component approach (see Appendix C).
  - Provision of, or support for use of, alternative transport modes.
- Medium efficacy
  - Vehicle ignition technology (smart-key, smart-licence).
  - Fitness-to-drive assessment by road authority; inclusive of online medical reports.
  - Passive alcohol sensor (warning).
- Low efficacy
  - Public education, incl. community engagement / alcohol and other drug (AOD) sector partnerships.
  - Fitness-to-drive assessment administered by health professionals.
  - Behavioural interventions (e.g., online)

The provision of, or facilitation of the use of, alternative transport modes was considered to be an applicable countermeasure for BAC positive drivers if they had any prior traffic offence and had been involved in a crash in the past year or had driven unlicensed. Accordingly, 6.3% of MAIS 1+ crashes would be sensitive to this potentially high efficacy countermeasure.

TABLE 3.4 MEASURES TO ADDRESS DRIVING UNDER THE INFLUENCE OF ALCOHOL AND ILLICIT DRUGS

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention							
						Impairing influence of alcohol (BAC)				Impairing influence of an Illicit drug (all types)			
	Description of measure	SSE	Int. cat.	Efficacy‡	Horizon	MAIS 1+ (n = 45, 11.3% of 400)		MAIS 3+ (n = 26, 13.8% of 188)		MAIS 1+ (n = 51, 12.8% of 400)		MAIS 3+ (n = 33, n = 17.6% of 188)	
						N	%	N	%	N	%	N	%
	Awareness												
1	Public education, incl. community engagement and Alcohol and Other Drug (AOD) sector partnerships	D	H-0	Low	Now	45	11.3%	26	13.8%	51	12.8%	33	17.6%
	Licensing												
1	Fitness-to-drive assessment (health professionals)	D	H-2	Low	Now	45	11.3%	26	13.8%	51	12.8%	33	17.6%
1	Fitness-to-drive assessment by road authority following self or health profession referral, and/or offence	D	H-2	Medium‡	Short-term	45	11.3%	26	13.8%	51	12.8%	33	17.6%
1	Provision of, or facilitation of alternative transport (concurrent with licence suspension/disqualification)[a b]	D	H-2	High‡	Short-term	25	6.3%	15	8.0%	51	12.8%	33	17.6%
	In-vehicle detection systems												
1	Active (manual) alcohol interlock (intervening)[c]	V	H-5	High	Now	45	11.3%	26	13.8%	n/a	n/a	n/a	n/a
1	Passive alcohol sensor (warning)	V	H-5	Medium‡	Medium-term	45	11.3%	26	13.8%	n/a	n/a	n/a	n/a
1	Passive alcohol sensor with interlock (intervening)	V	H-5	High‡	Medium-term	45	11.3%	26	13.8%	n/a	n/a	n/a	n/a
1	Drug interlock (intervening) via passive detection[d]	V	H-5	High‡	Medium-term	n/a	n/a	n/a	n/a	51	12.8%	33	17.6%
	Enforcement												
1	Enforcement (generalised, site specific) plus public education[e]	D	H-3	High	Now	45	11.3%	26	13.8%	51	12.8%	33	17.6%
1	Enforcement (expand roadside testing to include additional illicit substances) plus public education[f]	D	H-3	High	Now	n/a	n/a	n/a	n/a	7	1.8%	4	2.1%
1	Enforcement - post-offence sanctions (at roadside, impoundment, licence suspension)[g]	D	H-3	High‡	Short-term	45	11.3%	26	13.8%	51	12.8%	33	17.6%
	Countermeasures incorporating behavioural interventions and/or therapeutic management approach (based on crash involvement, roadside detection, or other referral)												
1	Integrated risk-based sanction and behavioural intervention (inclusive of therapeutic management) approach for the optimal management of drivers post-detection[g]	D	H-1-2,3	High‡	Short-to-medium term	45	11.3%	26	13.8%	51	12.8%	33	17.6%

‡ Efficacy assessments estimated for future measures; evaluation of countermeasure effect among relevant cohorts will be required.
Notes: Size of crash problem addressed: drivers impaired by alcohol and other drug drivers.
Countermeasures relevant to offenders (at roadside or crash-involved): a. Conditional on prior BAC offence or detected unlicensed. b. Any illicit-drug positive result.
c. Alcohol interlock removal conditional on sustained violation-free period, as part of re-licensing; highly efficacious while fitted. Future vehicle regulations: UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e
d. Potential technology includes driver monitoring systems (currently under development; driver impairment protocols by NCAP; see references at Section 4.1.4, below).
e. Outcome is prevention of AOD-driving episodes; if so, detection and removal from the road.
f. Expand testing regime to include cocaine, heroin, GHB (gamma hydroxybutyrate).
g. Enhanced post-offence management of AOD offenders through a combined sanctions – see Appendix C for broad outline of the approach. Outcome: address propensity to drive after AOD use, over and above generalised prevention, detection and removal.

3.1.6 A note on managing drowsy driving and concurrent use of Alcohol and Other Drugs (AOD)

The *ECIS Report 3* presented data where crashes involved a drowsy driver and/or a driver impaired by the effects of AOD (*ECIS Report 3*, Figure 3.2a, Figure 3.2b).

The effects of AOD use and/or driver drowsiness was evident in 37.7% (n = 151 of 400) of MAIS 1+ crashes and 43.6% (n = 82 of 188) of MAIS 3+ injury crashes. More specifically,

- The combined influence of AOD and drowsiness was seen in 6.5% of MAIS 1+ crashes (n = 26 of 400) and 8.0% of MAIS 3+ crashes (n = 15 of 188).
- The influence of AOD (excluding drowsiness) was seen in 13.3% of MAIS 1+ crashes (n = 53 of 400) and 17.0% of MAIS 3+ crashes (n = 32 of 188).
- The influence of drowsiness (excluding AOD) was seen in 18.0% of MAIS 1+ crashes (n = 72 of 400) and 18.6% of MAIS 3+ crashes (n = 35 of 188).

These factors were more prominent in Lane Departure crashes than Across Path and Rear Impact crashes (see *ECIS Report 3*, Figure 3.2b).

While this data highlights the concurrent nature of risk factors, from a countermeasure perspective it remains important to address each risk factor in isolation. As with all risk factors, failure to successfully address these at their position of influence in the crash sequence means that the driver progresses through each phase until ultimately a crash occurs, at which point energy management countermeasures remain essential to protect drivers from injury.

3.1.7 Measures to address factors associated with misuse/abuse of prescription medications

The impairing effect of the misuse/abuse of selected prescription medications (i.e., benzodiazepines, opioids) was a contributing factor for 7% (n = 28 of 400) of hospitalised ECIS case drivers (MAIS 3+ injured drivers, 8.5%, n = 16 of 188). Misuse/abuse of these prescription medications was somewhat higher for drivers involved in Lane Departure crashes (10.9%, n = 22 of 202) (*ECIS Report 3*, Table 3.1.1).

Measures applicable to the management of prescription drug misuse/abuse include awareness measures (i.e., driver, community), measures relating to licensing, vehicle ignition technology, enforcement-based approaches, and behavioural-focussed interventions (Table 3.5). Application of these measures play an important role in mitigating or preventing these crashes.

High-efficacy measures are included; however, none are currently in operation or available for use. The use by road agencies of prescription medication sentinel systems (e.g., *Safe Script)*, based on referral, offer a means of identifying the most at-risk drivers with a view of offering intervention programs to safely manage their driving. This process can also function as an entry-point to health services for those in need as part of an enhanced fitness-to-drive model.

Current approaches, including fitness-to-drive processes are also identified, but with enhancements including the adoption of health-based case management behavioural and therapeutic intervention approaches.

3.1.8 Measures to address addiction-related medical conditions

A subset of drivers (8.5%, n = 34 of 400) had a recognised pre-existing medical condition associated with substance use (i.e., alcohol, illicit drugs, abuse of prescription medication). This was based on a combination of ICD codes and prescribed use of medications for the management of drug dependence (excluding nicotine). Drivers meeting this criterion were more common among ECIS case drivers injured in Lane Departure crashes (12.9%, n = 26 of 202) than Rear Impact (7.2%, n = 5 of 69) or Across Path crashes (2.5%, n = 3 of 120).

While the mere presence of these conditions did not infer a contributory role for the crash, the concurrent use of alcohol, illicit drugs and/or misuse/abuse of prescription medications among this driver cohort was high. A range of measures to address this complex area were those used in the management of drink-driving, drug-driving, and the misuse/abuse of prescription medications (Table 3.5).

TABLE 3.5 MEASURES TO ADDRESS HEALTH-RELATED THREATS TO NORMAL DRIVING: MISUSE/ABUSE OF MEDICATION AND ADDICTION-RELATED MEDICAL CONDITIONS

ISC Phase	Intervention: Description of measure	SSE	Int. Cat.	Efficacy#	Horizon	Misuse/abuse of prescribed Schedule 8 medication with impairment† MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%	Medical condition (alcohol, addiction illicit, abuse/misuse prescription medication) ‡ MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
	Awareness												
1	Public education, including community engagement / AOD sector partnerships	D	H-0	Low	Now	28	7.0%	16	8.5%	31	7.8%	19	10.1%
	GP management and healthcare												
1	GP education and management, referral to AOD sector	D	H-1	Low	Now.	28	7.0%	16	8.5%	31	7.8%	19	10.1%
	Licensing												
1	Fitness-to-drive assessment (health professionals)	D	H-2	Low	Now	28	7.0%	16	8.5%	31	7.8%	19	10.1%
1	Fitness-to-drive assessment (road authority), including use of online medical reports, and on-going monitoring, and provision of, or facilitation of alternative transport modes where required (i.e., licence cancellation) or modified licence; following self or health profession referral, or offence.	D	H-2	Medium‡	Short-term	28	7.0%	16	8.5%	n/a	n/a	n/a	n/a
1	Fitness-to-drive assessment (road authority), inclusive of proactive stepped care (see above for elements, with in-vehicle detection systems where appropriate.	D	H-2	High‡	Short-term	n/a	n/a	n/a	n/a	31	7.8%	19	10.1%
1	Prescription medication sentinel system (use by road agencies)[a], coupled with fitness to drive countermeasure (see above for elements)	D	H-2	Medium‡	Short-term	28	7.0%	16	8.5%	31	7.8%	19	10.1%
	In-vehicle detection systems												
1	Active (manual) alcohol interlock (intervening) [part of fitness-to-drive approach][b]	V	H-5	High‡	Short-term	n/a	n/a	n/a	n/a	14	3.5%	8	4.3%
1	Drug interlock (intervening) via passive detection [part of fitness-to-drive approach][c]	V	H-5	High‡	Medium-term	n/a	n/a	n/a	n/a	21	5.3%	13	6.9%
	Enforcement												
1	Enforcement (increase type of drugs tested at roadside to include Schedule 8 (S.8) opioid analgesics / benzodiazepine medications), public education and supporting health-driver licensing management through fitness-to-drive program (see above)[d]	D	H-3	High‡	Short-term	28	7.0%	16	8.5%	n/a	n/a	n/a	n/a
	Countermeasures incorporating behavioural interventions and/or therapeutic management approach (based on crash involvement, roadside detection, or other referral)												
1	Behavioural interventions (online, in-person)	D	H-1,2,3	Low	Now	28	7.0%	16	8.5%	31	7.8%	19	10.1%
1	Integrated risk-based sanction and behavioural intervention (inclusive of therapeutic management) approach for the optimal management of drivers post-detection[d]	D	H-1-2,3	High‡	Short-to-medium term	28	7.0%	16	8.5%	n/a	n/a	n/a	n/a

Efficacy assessments estimated for future measures; evaluation of countermeasure effect among relevant cohorts will be required.

† S.8: Schedule 8 medications (select benzodiazepines, opioid analgesics). ‡ medical condition based on ICD hospital codes indicating pre-existing health condition and/or prescribed agents used in (management) of drug dependence (excluding nicotine) – alcohol and other drug (AOD)/prescription medication misuse/abuse not necessarily a contributing factor for crash.

a: e.g., SafeScript; PharmAssist. b. Alcohol interlock removal conditional on sustained violation-free period, as part of re-licensing.

c. Potential technology includes driver monitoring systems (currently under development; driver impairment protocols by NCAP, see references at Section 4.1.4, below).

d. Enhanced post-offence management – see Appendix C for broad outline of the approach. e. Outcome is prevention of impaired driving episodes; if so, detection and removal from the road.

3.1.9 Measures to address driver mental health and/or psychological distress

The effects of mental health conditions and/or psychological distress experienced by a driver — and inclusive of self-harm — played a contributory role in 12.5% of crashes (n = 50 of 400; MAIS 3+: 15.4%, n = 29 of 188). This risk factor was more prominent in Lane Departure crashes (17.3%, n = 35 of 202; MAIS 3+: 19.8%, n = 23 of 116) than other crash types. This risk factor is complex to manage, with this reflected in the low – medium countermeasure efficacy ratings.

Identified countermeasures focus on ensuring driver welfare and safety whilst ensuring maximum mobility. Measures include public education / awareness initiatives centred on the link between mental health and driving, licensing assessment measures, and specialist mental health treatment and support facilitated by medical (general) practitioners. Supporting the use or provision of alternative transport modes represents a high efficacy option; this may serve as a supplemental (temporary) measure within the fitness-to-drive assessment framework.

This remains an important area for road safety and broader society to address given the relatively high proportion of crashes where the effects of psychological distress or mental health symptoms played a direct role in the occurrence of these crashes. Such requirements are not envisaged to be long-standing, rather, to address acute psychological distress.

TABLE 3.6 MEASURES TO ADDRESS HEALTH-RELATED *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat.	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Mental health condition(s) and/or psychological distress (inclusive of self-harm)									
	Awareness								
1	Public education, including GP partnerships	D	H-0	Low	Now	50	12.5%	29	15.4%
	GP management and healthcare								
1	GP education and management, referral to mental health sector (with mobility supports provided)	D	H-1	Medium	Now	50	12.5%	29	15.4%
	Licensing								
1	Fitness-to-drive assessment and advice (health professionals)	D	H-2	Low	Now	50	12.5%	29	15.4%
1	Fitness-to-drive assessment by road authority following self or health professional referral	D	H-2	Medium	Now	50	12.5%	29	15.4%
1	Fitness-to-drive assessment (road authority), inclusive of proactive stepped care in a case management style approach, with health provider engagement	D	H-2	High‡	Short-term	50	12.5%	29	15.4%
1	Provision of, or facilitation of alternative transport modes (component of proactive stepped case fitness-to-drive approach, administered by road authority) (see above)	D	H-2	High‡	Short-term	50	12.5%	29	15.4%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect among relevant cohorts will be required.

3.1.10 Measures to address the sudden onset of physical health (medical) conditions on driving

The impact on driving of the sudden onset of medical conditions (e.g., cardiac events, epilepsy, loss of conscious state due to neurological or diabetic conditions) whilst driving was observed in 10.0% (n = 40 of 400) of ECIS crashes (MAIS 3+: 9.0%, n = 17 of 188). This risk factor was more prominent among drivers involved in Rear Impact crashes (15.9%, n = 11 of 69).

While the medical event was associated with a pre-existing condition for a subset of drivers, this was not always known. Indeed, several drivers were asymptomatic pre-trip.

Notwithstanding this, public education, fitness-to-drive assessments, the provision of - or assistance with - alternative transport where appropriate, and GP education and management of the driver, represent feasible countermeasures (Table 3.7). Fitness-to-drive assessments by the road authority have a higher efficacy (medium) than those conducted by general practitioners (low) due to the ability of road authorities to place conditions on a driver's license, as well as providing advice and alternatives to driving.

As with managing drowsy drivers, near-term technology-based countermeasures designed to assess driver health in real-time are directly relevant to the driving phase. These are discussed in the following chapter where measures designed to manage *Deviations from Normal Driving* are presented.

3.1.11 Measures to address the impacts of acute illness on driving

The effects of driver ill-health were seen in 5.5% of crashes (n = 22 of 400). Acute illness included respiratory illness, including influenza and colds, fever, and gastrointestinal distress, among other symptoms. Countermeasures in these instances relate to GP management and healthcare (i.e., treatment, advice), and the provision of - or assistance with - alternative transport where appropriate.

3.1.12 Measures to address the impacts of pre-existing sensory and/or physical impairment on driving

The effects of pre-existing impairment were seen in 4.0% (n = 16 of 400) crashes. These include impairments related to mobility / movement, hearing and/or vision. Countermeasures include GP management and healthcare, with appropriate advice in relation to medication use and alternative modes of transport (see Table 3.7).

3.1.13 Measures to address the impacts of impaired driver cognition

Compromised, or impaired driver cognition was evident as a contributing factor in 6.3% (n = 25 of 400) of MAIS 1+ ECIS crashes (MAIS 3+: 6.4%, n = 12 of 188). Impaired driver cognition was based on complete case information, inclusive of medical records. Driver decision-making, including error at the vehicle controls, was a key consideration. Driver age was not a consideration in this assessment.

Countermeasures to address impaired driver cognition are 'pre-trip' based, and include GP management and healthcare, as well as licensing requirements in the form of an enhanced licence renewal process and enhanced fitness-to-drive licensing assessments (see Table 3.7).

Enabling easier and more affordable access to public transport, taxis and rideshare services may also be considered; these would represent a high efficacy countermeasure by avoiding the need for this cohort to continue to drive a vehicle for daily activities.

TABLE 3.7 MEASURES TO ADDRESS HEALTH-RELATED *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention: Description of measure	SSE	Int. cat.	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Effects of physical health (medical) condition (e.g., epilepsy, cardiac events / syncope; excludes diagnosed sleep apnoea)									
	Awareness								
1	Public education	D	H-0	Low	Now	40	10.0%	17	9.0%
	Licensing								
1	Fitness-to-drive assessment (health professionals)	D	H-2	Low	Now	40	10.0%	17	9.0%
1	Fitness-to-drive assessment by road authority following self or health professional referral	D	H-2	Medium	Now	40	10.0%	17	9.0%
1	Fitness-to-drive assessment (road authority), inclusive of proactive stepped care in a case management style approach, with health provider engagement	D	H-2	High‡	Short-term	40	10.0%	17	9.0%
1	Provision of, or facilitation of alternative transport modes (component of proactive stepped case fitness-to-drive approach, administered by road authority) (see above)	D	H-2	High‡	Short-term	40	10.0%	17	9.0%
	GP management and healthcare								
1	GP education and management	D	H-1	Low	Now	40	10.0%	17	9.0%
Risk factor: Sensory or physical impairment (i.e., vision, hearing, movement / mobility-related)									
	GP management and healthcare								
1	GP education and management	D	H-1	Low-to-Medium	Now	16	4.0%	5	2.7%
	Licensing								
1	Fitness-to-drive assessment (health professionals)	D	H-2	Low	Now	16	4.0%	5	2.7%
1	Fitness-to-drive assessment by road authority following self or health professional referral	D	H-2	Medium	Now	15	3.8%	5	2.7%
1	Fitness-to-drive assessment (road authority), inclusive of proactive stepped care in a case management style approach, with health provider engagement	D	H-2	High‡	Short-term	15	3.8%	5	2.7%
1	Provision of, or facilitation of alternative transport modes (component of proactive stepped case fitness-to-drive approach, administered by road authority) (see above)	D	H-2	High‡	Short-term	15	3.8%	5	2.7%
Risk factor: Acute illness (transient, e.g., influenza)									
	GP management and healthcare								
1	GP education and management (on symptom management, medication impacts, alternative transport)	D	H-1	Low to Medium	Now	22	5.5%	9	4.8%
Risk factor: Driver cognition (compromised, impaired)									
	GP management and healthcare								
1	GP education and management (on symptom management, medication impacts, alternative transport)	D	H-1	Low-to-Medium	Now	25	6.3%	12	6.4%
	Licensing								
1	Fitness-to-drive assessment (road authority), inclusive of proactive stepped care in a case management style approach, with health provider engagement	D	H-2	High‡	Short-term	25	6.3%	12	6.4%
1	Licence renewal in person (no test required) [if ≥ 75 years of age]	D	H-2	Low-to-Medium	Now	21	5.3%	9	4.8%
1	Licence renewal in person with onsite test (practical) and cognitive assessment [if ≥ 75 years of age]	D	H-2	High‡	Short-term	21	5.3%	9	4.8%
1	Provision of, or facilitation of alternative transport modes (including use of Seniors Card as form of legally valid identification; for use in taxi and rideshare)	D	H-2	Low-to-Medium	Now	23	5.8%	11	5.9%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect among relevant cohorts will be required.

3.2 MANAGING VEHICLE-RELATED *THREATS TO NORMAL DRIVING*

Vehicle-related *Threats to Normal Driving* were those where the tyre, braking, suspension, and lighting systems were deficient prior to the commencement of the trip in which the crash occurred.

Vehicle conditions that contributed to crash occurrence were:

1. Poor tyre condition, including poor tyre tread, unbalanced, or mismatched tyres (4.8%, n = 19 of 400).
2. Critical vehicle malfunction where the steering and/or suspension system failed (1.3%, n = 5 of 400).
3. Vehicle lighting systems not functional as required (0.5%, n = 2 of 400).

These risk factors reflect basic vehicle condition and the need to ensure that the vehicle is in working order and is roadworthy. As such, periodic vehicle inspection programs are one countermeasure approach — albeit of low efficacy — while technology-based solutions are likely to be more efficacious at informing drivers in real-time of vehicle-related problems. These include Tyre Pressure Monitoring Systems (TPMS) and tread warning systems, noting that the efficacy (i.e., rated as medium) of these systems is dependent on the driver taking steps to remedy the problem. Vehicle systems can also warn the driver that lightbulbs need replacement.

A small number of crashes occurred directly due to a trailer or load becoming disconnected from the towing vehicle (0.8%, n = 3 of 400). Driver education represented one countermeasure option, as do trailer stability control systems. Such systems can play a role in improving safety, although this relates to improving stability as opposed to preventing disconnection due to connection error or other connection structural defect.

While the percent contribution of these factors to the overall road trauma problem is small, these vehicle-related problems represent basic roadworthiness requirements. The failure to meet these requirements represented a key contributing factor to the crash event in each case. For this reason, attention should focus on addressing these vehicle operation risk factors.

TABLE 3.8 MEASURES TO ADDRESS VEHICLE-RELATED THREATS TO NORMAL DRIVING

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	MAIS 1+ %	MAIS 3+ (N = 188) N	MAIS 3+ %
Risk factor: Tyre condition, includes poor tyre tread and/or underinflated tyres (ECIS Case [A] vehicle)									
1	Tyre pressure monitoring system (TPMS)[53]	V	H-5	Medium	Short-term	18	4.5%	10	5.3%
1	Tread warning	V	H-5	Medium‡	Medium-term	19	4.8%	11	5.9%
1	Periodic vehicle inspection (condition of suspension, tyre, windscreen, and headlights)	V	H-0	Low[54,55]	Now	19	4.8%	11	5.9%
Risk factor: Suspension / mechanical condition resulting in critical vehicle malfunction									
1	Periodic vehicle inspection (suspension)	V	H-0	Medium	Now	2	0.5%	1	0.5%
Risk factor: Vehicle lighting systems (i.e., indicators, brake lights) not working									
1	Periodic vehicle inspection (condition of suspension, tyre, windscreen, and headlights)	V	H-0	Low[54 55]	Now	2	0.5%	0	0.0%
1	Vehicle light bulb warning systems	V	H-0	Low	Now	2	0.5%	0	0.0%
Risk factor: Towing: Trailer and/or object unstable or detached									
1	Education / requirements on load carrying	D	H-0	Low	Now	3	0.8%	3	1.6%
1	Trailer stability control	V	V-2	Low‡	Medium-term	3	0.8%	3	1.6%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.

53 UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e

54 Martín-delos Reyes LM, Lardelli-Claret P, García-Cuerva L, Rivera-Izquierdo M, Jiménez-Mejías E, Martínez-Ruiz V. Effect of Periodic Vehicle Inspection on Road Crashes and Injuries: A Systematic Review. International Journal of Environmental Research and Public Health.. 2021 Jun 15;18(12):6476.

55 Elevated crash risk for vehicles not subject to periodic vehicle inspection is demonstrated by: Blows S, Ivers RQ, Connor J, Ameratunga S, Norton R. Does periodic vehicle inspection reduce car crash injury? Evidence from the Auckland Car Crash Injury Study. Australian and New Zealand Journal of Public Health. 2003;27(3):323-7. This suggests benefit *may potentially* be up to medium efficacy if applied to select vehicle cohorts rather than a universal scheme.

3.3 MANAGING ROAD AND ROAD INFRASTRUCTURE-RELATED *THREATS TO NORMAL DRIVING*

Being the one fixed component of the system in which the driver and vehicles vary at any point in time, the level of safety afforded by the road and road infrastructure —inclusive of the speed limit — is a key determinant of the level of road trauma that occurs. That is, the road and the road environment is the operating platform for road users, and hence, shapes safety and mobility. Consequently, any deficiency in the design and/or operating conditions of the road and road infrastructure can lead to safety-critical events (SCE) including, in the worst case, crashes and consequent serious injury.

As presented in *ECIS Report 3* (see Table 3.1.3), there were aspects of the road and road-infrastructure that represented *Threats to Normal Driving* and played a contributory role in crashes examined in the ECIS program. These factors, along with relevant countermeasures, are presented in Tables 3.8, 3.9, and 3.10. These are briefly described below.

3.3.1 Measures to address the impact of weather conditions impacting driver vision

Weather-related factors (i.e., rain, dust, glare) were seen to play a contributory role by negatively impacting driver vision in 2.8% (11 of 400) of crashes, this being higher in Across Path crashes (5.8%, n = 7 of 120). Daytime Running Lights (DRL) can play a role in mitigating these effects, either being operational to counter high glare scenarios (7 of 400 crashes, 1.8%) or being designed to counter glare and rain (1.3%, n = 5 of 400).

Other technology solutions such as Cross-Traffic Alert (CTA) and AEB, for instance, can play a role in mitigating these impacts. Likewise, infrastructure solutions can also play a role in managing scenarios where the two available DRL-based countermeasures may not apply. These measures are outlined in the next chapter.

3.3.2 Measures to address the impact of road surface risk factors and foreign substances on roads

Pavement surface was a contributing factor to crashes in two ways:

1. Through negatively influencing vehicle stability and vehicle-surface contact friction due to structural road defects, and
2. Through the presence of foreign substances on the road surface, such as standing water and oil, negatively impacting vehicle stability and vehicle-surface contact friction.

These deficiencies were contributing factors in 6.3% (MAIS 1+, n = 25 of 400) and 4.5% (n = 18 of 400) of ECIS crashes, respectively. These factors were most prominent in Lane Departure crashes (11.4%, n = 23 of 202; 7.9%, n = 16 of 202), which accounted for all but two of the crashes where these factors were evident.

Identified countermeasures to address these risk factors include (Table 3.9):

- High efficacy
    - Improving the road surface by management of unsealed surfaces to correct corrugations (see also unsealed road entry in Table 3.8); correction of pavement defects including 'bleeding' of the pavement, potholes, and surface changes; improving drainage, and surface treatments to increase the friction coefficient of the road surface.
- Medium efficacy
    - Provision of information to drivers, including through in-vehicle road surface alerts and C-ITS advanced warning systems, either to inform drivers of conditions, or to provide dynamic speed advisory alerts with the intention of the driver moderating their travel speed. These systems can play a role when oil and other similar substances are present on the road.

The applicability of these measures is independent of vehicle stability control systems and any other factors including vehicle-related *Threats to Normal Driving*.

Adverse road geometry was a contributing factor in a small proportion of crashes (2.5%, n = 10 of 400), with 7 of the 10 crashes being Lane Departure crashes (3.5%, 7 of 202). Correction of the adverse curvature through realignment represents the primary (medium efficacy) countermeasure to address this risk factor, and by extension, these crashes.

Three crashes occurred where the poor condition of an unsealed road was classified to have acted as a contributing factor for the crash.

TABLE 3.9 MEASURES TO ADDRESS ROAD AND ROAD INFRASTRUCTURE-RELATED *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Driver vision obscured by weather conditions (i.e., rain, fog, glare)									
1	Light and rain sensor – automatic control of lights-on (Daytime Running Light; DRL) function and windscreen wipers	V	H-6	Medium	Now	5	1.3%	2	1.1%
1	Daytime Running Light (DRL) for high glare scenarios	V	H-6	Low	Now	7	1.8%	3	1.6%
Risk factor: Pavement surface having a negative impact on vehicle stability and friction (Note: includes structural road defect including to edge-line, surface defect, unsealed surface poorly maintained with corrugations; rutting; 'bleeding' of pavement surface; potholes; surface changes)									
1	Improve surface (i.e., grade-unsealed, improve friction, defects, drainage)	R	R	High	Now	25	6.3%	10	5.3%
1	Road surface alert (low friction surfaces): vehicle-based traction control system	R	H-6	Medium	Now	25	6.3%	10	5.3%
1	C-ITS: advanced vehicle warning systems	V	H-6	Medium‡	Medium-term	25	6.3%	10	5.3%
1	C-ITS: dynamic speed advisory	V, S	H-6	Medium‡	Medium-term	25	6.3%	10	5.3%
Risk factor: Pavement surface conditions having a negative impact on vehicle stability due to foreign substances on road (i.e., oil, standing water)									
1	Pavement treatment (increase friction, drainage)	R	R	High	Now	18	4.5%	8	4.3%
1	Road surface alert (low friction surfaces): vehicle-based traction control system	V	H-6	Medium	Now	18	4.5%	8	4.3%
1	C-ITS enabled advanced vehicle warning systems	V	H-6	Medium‡	Medium-term	18	4.5%	8	4.3%
1	C-ITS enabled: dynamic speed advisory	V, S	H-6	Medium‡	Medium-term	18	4.5%	8	4.3%
Risk factor: Adverse curvature									
1	Modify camber, improve / realign curve radius	R	R	Medium	Now	10	2.5%	4	2.1%
Risk factor: Unsealed road (and related structural and surface conditions)									
1	Maintenance of unsealed road surface	R	R	Medium	Now	3	0.8%	1	0.5%
Risk factor: Latent risk due to road design (Note: combination of parameters indicates inherent risk by design; ECIS Report 1, Section 6.4.2; ECIS Report 3, Section 3.1.3)									
1	Comprehensive overhaul of road infrastructure including speed limit revision (Safe System assessment)	R, S	R	High	Now	88	22.0%	39	20.7%
Risk factor Absent, poor quality, or deceptive line markings									
1	Enhance / improve lane markings	R	R	Medium	Now	7	1.8%	5	2.7%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.

3.3.3 Measures to address poor quality or deceptive lane delineation

The absence, poor quality of, or deceptive line markings (1.8%, n= 7 of 400) was a contributory factor in crashes of a small proportion of ECIS case drivers. These crashes occurred in midblock locations.

Improvements include the use of advanced materials to enhance lane marking visibility, improving their layout and perceptual flow (Table 3.9). In some instances, their installation represents the primary countermeasure to address this risk factor.

3.3.4 Measures to address latent, or inherently risky road environments

Nearly one-quarter (22.0%, n = 88 of 400) of ECIS crashes occurred at locations that met pre-defined criteria as being inherently risky by design (see *ECIS Report 1*, Section 6.4.2; ECIS Report 3, Section 3.1.3). These criteria include a combination of road geometry, sight distance and associated factors, delineation, road surface, signage, and the speed limit (i.e., ≥ 80 km/h). Data presented in *ECIS Report 1* (Section 6.4.2) highlighted that driver error was twice as high at these locations. Notably, half of Across Path crashes (49.2%, n = 59 of 120; MAIS 3+: 45.3%, n = 24 of 53) occurred at these locations.

Due to the nature of the structural characteristics and the speed limit, a comprehensive overhaul following the outcome of a comprehensive *Safe System* assessment is necessary at these sites (Table 3.9).

3.3.5 Measures to address aspects of road edge delineation, lack of warning signs, driver sight lines and the risk associated with high-speed wet roads

Of the 400 ECIS case drivers 63.8% (n = 255) were injured in crashes that occurred at a midblock location.

Of these drivers 79.2% (n = 202) were injured in Lane Departure crashes, 18.4% (n = 47) were injured in Rear Impact crashes and 2.4% (n = 6) were injured in crashes classified as 'Other'.

Contributing factors for crashes at these midblock locations — most of which were Lane Departure crashes — included a lack of road edge delineation (2.7%, n = 7 of 255), lack of warning or poor placement of signs (5.9%, n = 15, n = 255), and driver vision (i.e., sight distance, angle) being negatively impacted by a fixed structure and/or road geometry (3.1%, n = 8 of 255).

The combined influence of a road infrastructure-environment risk (contributing) factor in combination with an 80+ km/h speed zone and wet weather demonstrated that this combined set of risk factors was apparent in 7.1% (n = 18 of 255) of crashes at midblock locations (i.e., 4.5% overall, 18 of 400) and in 7.9% of Lane Departure crashes (n = 16 of 202).

Countermeasures to address these contributing factors include (Table 3.10):

- Installation of guideposts and Raised Reflective Pavement Markers (RRPMs) to improve delineation (medium efficacy).
- Installation or improved placement of intersection, speed advisory, or other caution / information signs (medium efficacy).
- The removal, or relocation of, objects negatively impacting driver sight distance, particularly on roads with speed limits of ≥ 80 km/h, and/or, revise the road geometry, combined with speed limit reductions (high efficacy).
- Dynamic speed limit reduction associated with wet roads, on roads with a speed limit equal to or exceeding 80 km/h (high efficacy).

TABLE 3.10 MEASURES TO ADDRESS MIDBLOCK-SPECIFIC ROAD AND ROAD INFRASTRUCTURE-RELATED *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) [n = 255] N	%	MAIS 3+ (N = 188) [n = 129] N	%
Aspects specific to crashes at midblock locations (255 relevant midblock locations)									
Risk factor: Lack of appropriate road edge delineation									
1	Improve delineation using posts/ Raised Reflective Pavement Markers (RRPMs)	R	R	Medium	Now	7	1.8% [2.7%]	4	2.1% [3.1%]
Risk factor: Lack of warning signs or poor placement of signs									
1	Install, improve placement	R	R	Medium	Now	15	3.8% [5.9%]	9	4.8% [7.0%]
Risk factor: Vision obstructed by object and/or road geometry negative impact on sight distance									
1	Remove obstructing object and/or correct physical geometry, with concurrent speed limit reductions.	R, S	R	High	Now	8	2.0% [3.1%]	7	3.7% [5.4%]
Risk factor: Road infrastructure-environment risk (contributing) factor present in combination with 80+ km/h speed zone and wet (weather) conditions)									
1	Dynamic speed limit reduction: reduce when wet	R, S	R	High	Now	18	4.5% [7.1%]	6	3.2% [4.7%]

Note: Percent of MAIS 1+ (n = 400) and MAIS 3+ (n = 188); Midblock, n = 255 with n = 129 (50.6%) MAIS 3+. [%], percent of midblock locations assessed; Intensity (gradient) colours based on percent / number of midblock locations.

3.3.6 Measures to address intersection specific road infrastructure risk factors

At intersection crash locations (n = 145), poor sight distance, poorly located or not visible traffic signs, misleading road alignment, and lack of directional or hazard signage were all identified as contributing factors for ECIS crashes (see Table 3.10). Dynamic, congested, and high-volume traffic conditions were characteristic of 7.5% of crashes overall (n = 30 of 400), but 26.1% (n = 18 of 69) of Rear Impact crash locations.

Combined, one or more of these road infrastructure factors were present in 53.1% (n = 77 of 145) of intersection crashes, translating to 19.3% of all injured driver crashes (n = 77[56] of 400).

Countermeasures to address these contributing factors presented in Table 3.11 include:

- Installation of advance warning signs of intersection (medium efficacy).
- Installation of advance warning of intersection (signage, Variable Message Sign [VMS]) and perceptual countermeasures (road surface) with reduction in speed limit (medium efficacy).
- Installation of appropriate signage (including directional advice) and perceptual countermeasures (high efficacy).
- Improved placement (relocation) of traffic signs / signals (high efficacy).
- Correction of alignment and/or removal of structure if feasible, and installation of advance warning of intersection (signage, VMS) and perceptual road surface countermeasures (medium efficacy).
- Improved lighting at intersection (medium efficacy).
- Congestion alert (V2V / V2I, real-time driving) (medium efficacy / available in the medium-term).

The countermeasures all relate to the provision of information to the driver, as an advanced warning of an upcoming intersection, the provision of speed advisory signs enhanced via perceptual countermeasures, and

56 Includes: 65 Across Path crashes (54.2%, n = 65 of 120), 11 Rear Impact crashes (15.4%, n = 11 of 69) and 1 crash classified as 'Other' (n = 1 of 9).

measures aimed at alerting drivers to the potential for cross path vehicle conflict to occur at the approaching intersection. These basic road features were grossly inadequate, or entirely absent, at locations where ECIS crashes occurred. In all but one case (i.e., V2V / V2I congestion alert), these medium-to-high efficacy countermeasures are currently available. While these crashes represent up to 10% of the total trauma problem, at intersections the contribution of these factors to crashes ranges from 9.7% to as high as 26.9%. Hence, in volume terms, these factors represent a key threat to *Normal Driving*. Addressing these with what would be low-cost measures would bring substantial reductions in road trauma over the long term.

TABLE 3.11 MEASURES TO ADDRESS INTERSECTION-SPECIFIC ROAD AND ROAD INFRASTRUCTURE-RELATED *THREATS TO NORMAL DRIVING*

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400) [n = 145]		MAIS 3+ (N = 188) [n = 59]	
						N	%	N	%
Aspects specific to crashes at Intersections (contributing) factor present (note: 145 intersections assessed)									
Risk factor: Sight distance poor (limited or compromised through limited distance, intersection geometry, turning lanes, objects in eye-line, and/or road curvature)									
1	Install advance warning signs of intersection	R	R	Medium	Now	30	7.5% [20.7%]	13	6.9% [22.0%]
Risk factor: Sight distance poor with speed limit of 80+ km/h or higher									
1	Install advance warning of intersection (signage, Variable Message Sign, VMS) and perceptual countermeasures (road surface) with reduction in speed limit	R, S	R	High	Now	19	4.8% [13.1%]	9	4.8% [15.2%]
Risk factor: Lack of signage regarding hazard or directional instructions at intersection / of upcoming intersection									
1	Install appropriate signage (including directional advice) and perceptual countermeasures	R	R	Medium	Now	30	7.5% [20.7%]	16	8.5% [27.1%]
Risk factor: Traffic signs poorly located / not visible									
1	Improve placement (relocate) of traffic signs / signals	R	R	Medium	Now	39	9.8% [26.9%]	16	8.5% [27.1%]
Risk factor: Road alignment and/or intersection misleading with/without vision impeded due to roadside structure									
1	Correct alignment and/or remove structure if feasible	R	R	High	Now	35	8.8% [24.1%]	12	6.4% [20.3%]
1	Install advance warning of intersection (signage, Variable Message Sign, VMS) and perceptual countermeasures (road surface)	R	R	Medium	Now	35	8.8% [24.1%]	12	6.4% [20.3%]
Risk factor: No or sub-optimal lighting at intersection, with identified intersection risk factor (crash at night, dusk, dawn: low ambient light)									
1	Improve lighting at intersection	R	R	Medium	Now	14	3.5% [9.7%]	6	3.2% [10.2%]
Risk factor: Dynamic, congested high volume traffic environment									
1	Congestion alert (V2V / V2I, real-time driving)	V	H-6	Medium‡	Medium-term	30	7.5% [20.7%]	10	5.3% [16.9%]

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
Note: Percent of MAIS 1+ (n = 400) and MAIS 3+ (n = 188); Intersection, n = 145 with n = 59 (40.7%) MAIS 3+. [%], percent of number of intersection locations assessed; Intensity (gradient) colours based on number of intersection locations.

4 RESULTS – MEASURES TO MANAGE *DEVIATIONS FROM NORMAL DRIVING* THROUGH TO *CRITICAL SITUATIONS*

The philosophy that underpins the ISC is that from the time a trip commences, measures that support, encourage, or force the driver to return to a state of *Normal Driving* become the focus. This includes managing *Deviations from Normal Driving* (Phase 3) — this being the first step in the driving phase — through to *Critical Situations* (Phase 5) that require a more aggressive interventionist approach where the response of the driver becomes less important. As a general principle, vehicle-based technologies that intervene automatically – or demand a response – are rated as having high efficacy in addressing the specific risk factor. Target risk factors are those amenable to modification.

In *ECIS Report 3*, contributory factors were presented in a manner consistent with the phases of the ISC. This highlights the point of initiation and persistence of each factor in the crash sequence. It is then obvious that the need to intervene becomes more urgent as a driver moves through the ISC.

For ease, all countermeasures relevant to a specific trip-based risk factor are identified and presented together. This includes all countermeasures that address an individual risk factor that may exert its influence as a *Deviation from Normal Driving* (Phase 3), a driver act or other event that results in an emerging situation (Phase 4) and ultimately a critical situation. The countermeasures act to return the driver to a state of safe, or *Normal Driving*.

For completeness, countermeasures that ensure the basic requirements of *Normal Driving* are met — as reflected in Phase 2 of the ISC — are situated in Phase 1 and in Phase 3 of the ISC.

The presentation style is the same as that used in Chapter 3; that is, countermeasures common to all crash types are presented first, followed by countermeasures specific, or relevant only to, Lane Departure crashes (i.e., vehicle deviated from its travel lane) and Across Path crashes. Hence, select contributory factors relevant to Lane Departure crashes and Across Path crashes are also relevant to Rear Impact crashes as appropriate.

The objective in presenting this data is to highlight countermeasures that can eliminate serious injury trauma. With an understanding of contributing factors, as well as the function and purpose of countermeasures, crashes 'sensitive' to specific countermeasures were identified (refer *ECIS Report 3*).

For completeness, the proportion of crashes where each contributing factor was present is provided. This percent value reflects the size of the serious injury crash problem that can be addressed by the specified countermeasure.

To present this analysis, this chapter is structured as follows:

- Section 4.1 presents countermeasures for contributing factors that occur in all crash types.
- Section 4.2 presents countermeasures for contributing factors relevant to Lane Departure crashes, Across Path crashes at intersections, and Rear Impact crashes.

Note: Rear Impact crashes can occur due to a vehicle departing its travel lane (e.g., striking a parked vehicle) or on approach to, or at an intersection. Countermeasures applicable to these movements are discussed.

4.1 MEASURES COMMON TO ALL CRASH TYPES

4.1.1 Measures to address non-use of seat belts

The protective benefit of seat belt use is widely understood. Indeed, seat belt use is one the five *Safe Driver* compliance requirements (see *ECIS Report 1*, Table 8.1).

Non-use of a seat belt was evident in 6.8% of ECIS case drivers (n = 27 of 400; MAIS 3+: 7.4%, n = 14 of 188). Non-use of seat belts was higher among drivers involved in Lane Departure crashes (9.9%, n = 20 of 202; MAIS 3+: 10.3%, n = 12 of 116) compared to drivers injured in Across Path crashes (2.5%, n = 3 of 120; MAIS 3+: 1.9%, n = 1 of 53).

Countermeasures aimed at addressing the non-use of seat belts include:

- Enforcement of current seat belt laws with supporting public education.
- In-vehicle seat belt reminder systems.

Both types of countermeasures are, however, dependent upon driver response and action.

TABLE 4.1 MEASURES TO ADDRESS NON-USE OF SEAT BELTS

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Seat belt not worn (ECIS Case [A] driver)									
	Enforcement and Awareness								
3-5	Enhanced (targeted, intense) enforcement coupled with public education (includes sanction effect component for offenders)	D	H-3	High[a]	Now	27	6.8%	14	7.4%
	In-vehicle technology								
3-5	Seat belt reminder (SBR) systems (advisory)	V	H-5	Medium[b]	Now	27	6.8%	14	7.4%
3-5	Seat belt reminder (SBR) systems (intervening)	V	H-5	High[c]	Short-term	27	6.8%	14	7.4%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
a. Efficacy rating: reflects generalised and specific enforcement effects, coupled with public education on seat belt use. Outcome is seat belt use.
b. Efficacy rating: medium level of efficacy to address remaining non-compliance (in addition to enforcement/education effects).
c. Efficacy rating: expected high level of efficacy to address remaining non-compliance (over and above enforcement/education effects).

Advisory seat belt reminder systems can provide a visual and auditory warning to the driver of a non-belted occupant, while intervening seat belt reminders have escalation features that operate if the driver ignores the warnings and fails to fasten their seat belt. These interventions can include lowering the volume of the radio, de-powering the vehicle, or preventing the vehicle from being driven.

With the enhanced set of features, intervening seat belt reminder systems have a high level of efficacy in ensuring seat belt use. Protections against misuse of these systems include sensors in the seat to detect body weight, as well as sensors in the spool of the seat belt, in the B-pillar casing, and in the belt tongue to prevent the system being gamed (e.g., sitting on the clipped-in belt; wrapping the belt around the seat; inserting a second belt tongue into the clip).

Future opportunities may include the use of AI-capable driver monitoring systems that can detect seat belt use through visual confirmation.

4.1.2 Measures to address non-compliance with the speed limit

Compliance with the speed limit is an essential requirement of *Normal Driving*. Non-compliance with the speed limit was found in 27.0% (n = 108 of 400) of ECIS driver crashes. The level of non-compliance with the speed limit was higher among drivers sustaining MAIS 3+ injuries (36.2%, n = 68 of 188). While non-compliance with the speed limit was evident in all crash types, speed limit non-compliance was highest in Lane Departure crashes (34.2%, n = 69 of 202) (c.f. Across Path crashes: 23.3%, n = 28 of 120).

Countermeasures aimed at addressing the non-compliance with the speed limit include:

- Enforcement of the speed limit with supporting public education.
- In-vehicle speed assistance technology (e.g., ISA).
- Roadside (external) information signs and systems.

All three countermeasure types play a role in shaping speed limit compliance behaviour of drivers. Enforcement activity complemented with concurrent public education plays a critical role in shaping driver attitudes toward speeding and compliance behaviours.

Informing drivers of the speed limit using roadside signage is a longstanding approach, however technology offers new approaches. This includes in-vehicle speed sign warning systems (e.g., Traffic Sign Assist) embedded in the vehicle console. This technology, using GIS map data supplemented by camera-based sign recognition systems that can account for work-zones and variable speed limits (e.g., time-based school zone speed limits) can provide drivers with knowledge of the speed limit where they are travelling. This architecture forms the basis of Intelligent Speed Assist (ISA) technology. ISA systems, depending on their warning (e.g., flash, beep if over the speed limit) or intervening features (e.g., pedal pushback), can be highly efficacious at ensuring compliance with the speed limit.

Highly visible Variable Message Signs (VMS) – including speed detection feedback signs - also have value, particularly in locations where reduced advisory speed limits are important for safety (e.g., curves; difficult intersections).

Given the high proportion of crashes where non-compliance with the speed limit was a contributing factor to both crash occurrence and increased injury severity (see *ECIS Reports 1, 2, 3*), the implementation of countermeasures to address this behaviour is a high priority. To address this risk factor, and in the absence of 'always-on' intervening ISA systems in all vehicles, a suite of countermeasures is likely to be required.

TABLE 4.2 MEASURES TO ADDRESS NON-COMPLIANCE WITH THE SPEED LIMIT

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Non-compliance with posted speed limit									
	Enforcement and awareness								
3-5	Enhanced enforcement (targeted, intense) coupled with public education (includes sanction effect component for offenders)	D, S	H-3	High[a]	Now	108	27.0%	68	36.2%
	In-vehicle technology[b]								
3-5	Speed assistance - manual speed limiter	V, S	H-5	Low	Now	108	27.0%	68	36.2%
3-5	Speed assistance – speed sign recognition & warning	V, S	H-5	Medium	Now	108	27.0%	68	36.2%
3-5	Speed assistance - route based advisory	V, S	H-5	Medium	Now	108	27.0%	68	36.2%
3-5	Speed assistance – Intelligent Speed Assist (ISA) (advisory)	V, S	H-5	Medium	Now	108	27.0%	68	36.2%
3-5	Speed assistance – Intelligent Speed Assist (ISA) (intervening)	V, S	H-5	High	Now	108	27.0%	68	36.2%
	Advisory signs and cautions								
3-5	VMS - travel speed indicator	R, S	R	Low	Now	108	27.0%	68	36.2%

a. Efficacy rating: reflects generalised and specific enforcement effects, coupled with public education on seat belt use; outcome is speed limit compliance. High levels of compliance with the speed limit are seen; this high level of compliance is reflected in the ECIS Control speed measurement data.

b. Overview of current speed assistance systems: https://etsc.eu/intelligent-speed-assistance-isa/; outcome is speed limit compliance. Subject to UN Regulation: UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e

4.1.3 Measures to address driver speed choice and driving at inappropriate speed for the conditions

Distinct from compliance with the speed limit, travel speed was classified as inappropriate for the road and/or environmental conditions. Inappropriate travel speed, despite being within the posted speed limit, was a contributing factor in 11.8% of crashes; this behaviour was more common in Lane Departure crashes 18.8% (n = 38 of 202).

In-vehicle technology is an ideal countermeasure to manage inappropriate speed choice (Table 4.3). Real-time, in-vehicle speed sign recognition systems (e.g., Traffic Sign Assist) can inform the driver of dynamic speed limit changes and advisory speed signs, while route-based advisory systems can provide information to drivers of appropriate speeds based on fixed road characteristics, such as the presence of curves and compromised road surface conditions (e.g., low friction surfaces). These systems are capable of detecting travel speeds that are too high for the conditions, be that associated with one or more of wet weather, lower road surface fiction, aspects of road geometry (i.e., curves, Curve Warning), and congestion. These conditions were prevalent in a number of ECIS crashes, as shown in Table 4.3.

ISA can play an important role in managing vehicle speed by either encouraging speed compliance, more forcefully generating a driver response, or by managing the vehicle speed entirely. Intervening systems, when they become available, are expected to have a high level of efficacy in addressing this inappropriate speed choice.

These technology-based systems are extensions of compliance-related speed limit assistance technology. These systems would likely require inputs from vehicle control systems (e.g., braking, stability systems such as traction control, Electronic Stability Control [ESC]) and sensors to detect the external environment. While Curve Warning systems inform the driver of inappropriate speeds in curves, Active Curve Systems intervene to enhance stability in curves. These systems are likely to become available in the short-term.

Perceptual countermeasures are also effective in guiding an appropriate speed choice. These interventions, supported by (potentially variable) advisory speed signs and highly visible travel speed indicators can all play a role in assisting drivers to moderate their speed choice and adapting to prevailing environmental conditions.

TABLE 4.3 MEASURES TO ADDRESS DRIVING AT INAPPROPRIATE SPEED FOR THE CONDITIONS

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Inappropriate (compliant) travel speed for conditions / route (Note: excludes exceed speed limit)									
3-5	Speed assistance – advisory speed sign recognition & warning	V, S	H-6	Medium	Now	47	11.8%	20	10.6%
3-5	Speed assistance - route based advisory (adaptation)	V, S	H-6	Medium	Short-term	47	11.8%	20	10.6%
3-5	Speed assistance – Intelligent Speed Assist (ISA) (advisory)	V, S	H-6	Medium	Short-term	47	11.8%	20	10.6%
3-5	Speed assistance – Intelligent Speed Assist (ISA) (intervening)	V, S	H-6	High	Short-term	47	11.8%	20	10.6%
3-5	Curve warning#	V, S	H-6	Medium	Short-term	26	6.5%	12	6.4%
3-5	Active curve (intervening)#	V, S	H-6	High	Short-term	26	6.5%	12	6.4%
3-5	Advisory speed signs including vehicle activated signage#	R, S	R	Low	Now	25	6.3%	12	6.4%
3-5	Perceptual countermeasures (incl. curve alignment markers, rumble strips)#	R	R	Medium	Now	26	6.5%	12	6.4%
3-5	VMS - travel speed indicator	R, S	R	Low	Now	47	11.8%	20	10.6%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required. # Relevant only to crashes occurring on curves.

4.1.4 Measures to address driver inattention

Inattention is operationalised as:

- Distraction internal (e.g., passengers; in-vehicle controls, other activities) or external (e.g., wayfinding) to the vehicle.
- Distraction due to mobile phone use.
- Distraction due to an internal focus (i.e., thoughts).
- A lack of alertness (i.e., drowsiness, including falling asleep).
- A loss of conscious state due to the effects of a sudden medical event (e.g., cerebrovascular attack, myocardial infarction) resulting in compromised cognition, motor control, and/or sensory capability.

Using the definition above, driver inattention was a contributing factor in 66.8% (n = 267 of 400) of ECIS crashes. Driver inattention was common in Lane Departure crashes (74.3%, n = 150 of 202), Rear Impact crashes (72.5%, n = 50 of 69) and Across Path crashes (50.8%, n = 61 of 120).

While driver inattention can first be represented as a *Deviation from Normal Driving* (Phase 3), the consequence of driver inattention can be felt through the crash sequence. The primary intent of inattention-focussed countermeasures is to ensure drivers remain vigilant and attend to the driving task.

With its impact on safety becoming more significant as the driver moves towards a critical event, the nature of the countermeasure changes. This is reflected in the type of vehicle-based warnings given to the driver, both in terms of modality and intensity. Providing the driver with the opportunity to correct their aberrant behaviour is important from a technology acceptability viewpoint. Systems that match the intensity of the warning to the unfolding crash sequence, from relatively benign to very aggressive are optimal. Where drivers fail to respond and the crash sequence reaches the critical phase, intervention in driving is required.

Public education programs and *Attention Assist* vehicle technology systems countermeasures generally applicable to all forms of inattention (Table 4.4). Specific sources of inattention and associated measures are outlined below.

Currently available in-vehicle *Attention Assist* technology uses steering wheel sensors as a means of detecting driver inattention, while systems under development are incorporating camera-based *Driver Monitoring Systems (DMS)* for the detection of driver inattention. These DMS-based *Attention Assist* systems are the subject of current regulatory action[57] and will be incorporated into future NCAP test protocols.[58,59] DMS-based systems have been shown to be highly efficacious in the commercial vehicle sector.[60]

TABLE 4.4 MEASURES TO ADDRESS DRIVER INATTENTION

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Driver inattention – includes all forms of inattention including driver state and sudden sickness									
3-5	Public education programs (including peer programs)	D	H-0	Low	Now	267	66.8%	129	68.6%
3-5	Attention assist (warn)	V	H-6	Low	Now	267	66.8%	129	68.6%
3-5	Attention assist (warn) / Driver monitoring system (camera-based)	V	H-6	Medium	Short-term	267	66.8%	129	68.6%
3-5	Attention assist (intervene, e.g., steering assist)	V	H-5	High	Short-term	267	66.8%	129	68.6%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.

57 UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e

58 Fredriksson R, Lenné MG, van Montfort S and Grover C (2021) European NCAP Program Developments to Address Driver Distraction, Drowsiness and Sudden Sickness. Frontiers in Neuroergonomics. 2:786674.

59 Regulations and NCAP test protocols for DMS-based systems are relevant to all forms of driver inattention, including distraction, drowsiness, and other forms of impaired driving. The references here are applicable to all mentions of DMS that follow.

60 Fitzharris M, Liu S, Stephens AN, Lenné MG. The relative importance of real-time in-cab and external feedback in managing fatigue in real-world commercial transport operations. Traffic Injury Prevention. 2017;18(sup1):S71-S8.

4.1.4.1 Measures to address driver distraction from sources inside and outside the vehicle

Sources of in-vehicle distractions and distractions outside of the vehicle include:

- A focus on a person(s) or an object(s) inside or outside of the vehicle.
- A focus on vehicle controls not critical to the driving task (e.g., infotainment functions).
- The performance of non-driving activities in the vehicle (e.g., eating, applying makeup).
- An inward focus on thoughts (e.g., daydreaming)

One or more of these driver distraction behaviours was evident in 45% of crashes (n = 180 of 400) (MAIS 3+: n = 85 of 188, 45.2%). Driver distraction was consistently high across all crash types. That driver distraction influences such a high proportion of crashes makes it a high priority concern.

As with driver inattention more generally, relevant countermeasures are public education programs, which can include a peer-to-peer element, as well as in-vehicle technology (Table 4.5). Systems such as Attention Assist that are based on steering wheel inputs and provide audio and/or visual warnings to the driver are of value. However, the efficacy of these systems in returning the driver's attention to the driving task depends on acceptance of the device; being a 'warning-only' system, alerts can be ignored. Sophisticated systems that use escalating warnings across multiple modalities are a better solution than systems that use only a single warning type in one modality.[61]

Purely warning based systems (e.g., audio-tactile) are appropriate if the initial distraction event occurs as an early *Deviation from Normal Driving*. However, a more aggressive intervention is required if the driver continues to be distracted and the scenario moves to a Critical Situation where a crash is increasingly imminent.

Intervening systems have a higher level of efficacy with respect to safety due to direct inputs into the driving task. These systems may rely on camera-based Driver Monitoring Systems (DMS) as an input, which have a higher accuracy in detecting driver distraction due to use of multiple inputs and computer-based vision algorithms. These DMS, inclusive of intervening functions, are critical technologies that will address a significant contributing factor to crashes.

TABLE 4.5 MEASURES TO ADDRESS DRIVER DISTRACTION

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Inattention in form of distraction in and out of vehicle (Note: excluding mobile phone use)									
3-5	Public education programs (including peer programs)	D	H-0	Low	Now	180	45.0%	85	45.2%
3-5	Attention Assist (warn)	V	H-6	Low	Now	180	45.0%	85	45.2%
3-5	Attention Assist (warn) / Driver monitoring system†	V	H-6	Medium	Short-term	180	45.0%	85	45.2%
3-5	Attention Assist (intervene, e.g., steering assist)	V	H-6	High	Short-term	180	45.0%	85	45.2%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.

61 Horberry T, Mulvihill C, Fitzharris M, Lawrence B, Lenné M, Kuo J, et al. Human-Centered Design for an In-Vehicle Truck Driver Fatigue and Distraction Warning System. IEEE Transactions on Intelligent Transportation Systems. 2022;23(6):5350-9.

4.1.4.2 Measures to address driver distraction associated with mobile phone use

Distraction through use of a mobile phone use – involving manual handling of the device – whilst driving was a contributing factor in 3.8% of crashes (n = 15 of 400; MAIS 3+: 4.8%, n = 9 of 188).

The countermeasure approach is to achieve the non-use of mobile phones. As with distraction more generally, countermeasures include public education and in-vehicle technology (i.e., Attention Assist) (Table 4.6). Device-based solutions, such as automated 'drive mode' lock out functions are of use, however these depend on the user initially setting up this function on their phone and then not overriding its lockout function during a trip.

TABLE 4.6 MEASURES TO ADDRESS DRIVER DISTRACTION

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon‡	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Inattention in the form of using mobile phone (Note: manual use, held in hand)									
3-5	Public education programs (including peer programs)	D	H-0	Low	Now	15	3.8%	9	4.8%
3-5	Mobile phone 'drive' mode feature (use of)	D	H-5	Low	Now	15	3.8%	9	4.8%
3-5	Police enforcement (intercept) – infringement (specific and general deterrence effects)	D	H-3	Medium	Now	15	3.8%	9	4.8%
3-5	Enforcement - Mobile phone camera detection systems[62]	D	H-3	High	Now	15	3.8%	9	4.8%
3-5	Attention Assist (warn)	V	H-5	Low	Now	15	3.8%	9	4.8%
3-5	Attention Assist (warn) / Driver Monitoring System (DMS) / Occupant Status Monitor (OSM)† (camera-based)	V	H-5	High	Short-term	15	3.8%	9	4.8%
3-5	Attention assist (intervene, e.g., steering assist)	V	H-5	High	Short-term	15	3.8%	9	4.8%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.

In addition, due to the existing laws that ban the manual handling and use of mobile phones while driving, enforcement approaches apply. These enforcement approaches include police observation and intercept, as well as recently available automated mobile phone camera use detection systems. These automated enforcement systems have high efficacy due to the specificity of the offence detected and capacity for high volume application, supported by a range of penalties.

62 Introduced as a pilot program in NSW in 2019. (https://roadsafety.transport.nsw.gov.au/stayingsafe/mobilephones/technology.html) with expansion into Victoria in 2022. Further evaluation needed, however see: Stephens A, Stephan K, Newstead S. Estimation of the potential effectiveness of mobile phone camera enforcement in Victoria. Melbourne Vic Australia: MUARC, 2019.

4.1.4.3 Measures to address drowsy driving

'Driver state' relates to alertness. Within the case-level crash data, a distinction between driving in a drowsy state from those who fell asleep whilst driving was made. For the purposes of reporting however, 'drowsy driving' includes both, thereby acknowledging that alertness sits on a continuum with falling asleep being the extreme consequence of drowsiness.

Drowsy driving, inclusive of drivers falling asleep, was a contributing factor in the crash for 24.5% (n = 98 of 400; subset of asleep: 11.0%, n = 44 of 400) of injured drivers (MAIS 3+: 26.6%, n = 50 of 188; asleep: 13.3%, n = 25 of 188). Drowsy driving was prominent in Lane Departure crashes (35.6%, n = 72 of 202; asleep: 20.3%, n = 41 of 202).

While a driver being drowsy before commencing their trip represents a *Threat to Normal Driving* in the ISC, the impact of this lack of alertness on driving performance emerges once the trip commences. Degradation in alertness can also occur during the trip itself. Pre-trip (Phase 1, *see Section 3.1.4*) drowsy driving countermeasures do however include (Table 4.7):

- Public education initiatives, focussed on the risk of drowsy driving and preventative steps.
- For work-related crashes, fleet / shift-work specific 'fatigue' management policies.

These pre-trip countermeasures are included here only so that all drowsy driving relevant countermeasures appear together in the *Report*.

TABLE 4.7 MEASURES TO ADDRESS DROWSY DRIVERS

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Driver state/alertness: Drowsy (including fell asleep)									
3-5	Education on effects of drowsy driving	D	H-0	Low	Now	98	24.5%	50	26.6%
3-5	Fleet / work driving specific fatigue policies[a]	D	H-0	Medium	Now	8	2.0%	4	2.1%
3-5	Enforcement of impaired alertness and associated public education	D	H-3	Medium	Medium -term	98	24.5%	50	26.6%
3-5	Attention Assist (warn)	V	H-6	Low	Now	98	24.5%	50	26.6%
3-5	Attention Assist (warn) via DMS / Occupant Status Monitoring (OSM)[b]	V	H-6	Medium	Short-term	98	24.5%	50	26.6%
3-5	Attention Assist (warn), via DMS / OSM[b] (intervene, e.g., steering assist)	V	H-6	High	Short-term	98	24.5%	50	26.6%
3-5	Attention Assist via DMS / OSM[b] with vehicle takeover (steer, park) for a non-responsive driver)	V	V-2	High	Medium -term	44	11.0%	25	13.3%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
Notes: a Considers role of ECIS driver only.
b. Non-responsive driver recognised via DMS and/or steering wheel inputs; system requires integration with Auto Steer, Auto Stop and AECS / eCall if required.

Countermeasures to address drowsy driving once the trip commences include:

- Enforcement of impaired driver alertness, either through direct police observation of driving and/or through objective measurement of alertness levels noting this technology is not presently available.
- In-vehicle attention assist technology, with different levels of function and therefore efficacy (from low to high) including:
  - Attention Assist, using an auditory and/or visual warning.
  - Attention Assist, using an auditory and/or visual warning supported by Driver Monitoring System (DMS) / Occupant Status Monitoring (OSM) (i.e., visual assessment of the driver with/without biometric assessment).
  - Attention Assist, using an auditory and/or visual warning with an escalation to an intervention, such as steering assist (Auto Steer) and Auto Park. The system is supported by DMS / OSM (i.e., direct visual assessment of the driver). Drowsy drivers would be expected to respond to this high level of intervention, whilst those asleep would not and would require an even higher level of intervention for the crash to be prevented.
  - Attention Assist, using an auditory and/or visual warning with escalation to an intervention, (e.g., steering assist) supported by DMS / OSM, and where necessary, execute a complete vehicle takeover to prevent a crash. This countermeasure is applicable where drivers are non-responsive to all earlier warnings and interventions (11%, n = 44 of 400).

Here it is important to state that intervening Attention Assist technologies are not presently available but offer significant promise to address significant contributing factors for crashes.

4.1.4.4 Measures to address non-responsive drivers due to 'sudden sickness' (acute medical events)

As outlined in Section 3.1.10, an acute medical event resulting in a driver being non-responsive was a contributing factor in 10% of crashes (n = 40 of 400). Proportionately, these acute medical events were more common in Rear Impact crashes (15.9%, n = 11 of 69) and crashes classified as 'Other' (22.2%, n = 2 of 9), notwithstanding the small number of crashes.

While pre-trip countermeasures were identified (e.g., GP management; fitness-to-drive assessments), acute medical events can occur suddenly and without warning. Consequently, in-vehicle intervening driver state / occupant status monitoring (OSM) technology is an invaluable countermeasure. These systems, as shown in Table 4.8, are not presently available for implementation, but would be expected to have medium-to-high efficacy.

TABLE 4.8 MEASURES TO ADDRESS NON-RESPONSIVE DRIVERS (SUDDEN SICKNESS)

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Sudden sickness: acute medical illness/acute medical event resulting in non-responsive driver									
3-5	Attention Assist (warn), via DMS / OSM[a] (intervene, e.g., steering assist)	V	H-6	Medium	Short-term	40	10.0%	17	9.0%
3-5	Attention Assist via DMS / OSM[a] with vehicle takeover for a non-responsive driver, due to medical event)	V	V-2	High	Medium-term	40	10.0%	17	9.0%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
a. Non-responsive driver recognised via DMS and/or steering wheel inputs; system requires integration with Auto Steer, Auto Stop and AECS / eCall if required.

4.1.4.5 Measures to address non-responsive drivers

In total 21% (n = 84 of 400; MAIS 3+ 22.3%, n = 42 of 188) of ECIS case drivers were injured in crashes where a driver was non-responsive, either due to falling asleep (11%, n = 44 of 400) or having experienced an acute medical event (10.0%, n = 40 of 400). Intervening Attention Assist technologies are essential countermeasures to address the safety risk posed by non-responsive drivers.

4.1.5 Measures to address driver intentional self-harm

Intentional self-harm was seen in 1% of ECIS crashes (n = 4 of 400; MAIS +: 2.1% of 188), all of which were Lane Departure crashes (MAIS 1+; 2.0% of 202; MAIS 3+: 3.4% of 120) (Table 4.9).

While a range of measures to address driver mental health and/or psychological distress were presented in Section 3.1.9, in-trip measures to address these crash events have a heightened urgency. As far as possible, the conduct of a police intercept as a welfare check and onward referral to a health service is required. While this could be seen to be a high-efficacy countermeasure in addressing the immediate behaviour of concern, proactive implementation is recognised to be difficult. The rating of high efficacy reflects the 'in-principle' impact of actual interception prior to a critical event. This does not consider the probability of successful detection, which first requires direct observation of driving and related behaviours of concern by police, or police being notified by a concerned member of the public with sufficient time to intervene. Addressing these scenarios is both complex and time sensitive.

TABLE 4.9 MEASURES TO ADDRESS SELF-HARM WHILST DRIVING

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Driving to intentionally self-harm									
3-5	Police 'intercept' - welfare check and health-referral / assistance	D	H-3	High	Now	4	1.0%	4	2.1%

4.1.6 Measures to address driver vision impacted by environmental conditions and/or insufficient lighting at crash site

Measures to address weather-related factors (i.e., rain, dust, glare) negatively impacting driver vision were outlined in Section 3.3.1. These were Daytime Running Lights (DRL) and light/rain sensor linked DRL and windscreen wipers.

In addition, and to address the poor visibility stemming from insufficient lighting at crash locations, advanced adaptive vehicle lighting systems are relevant to 5.3% (n = 21 of 400) of crashes (Table 4.10). Optimised systems need to offer good on-road illumination with minimal glare, as per the IIHS Headlight Test and Rating Protocol (see https://www.iihs.org).

Where deficient, measures such as the installation of streetlights and improved delineation are outlined below.

TABLE 4.10 MEASURES TO ADDRESS VISIBILITY WHILST DRIVING

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Driver vision impacted - environmental conditions and/or insufficient lighting at site									
3-5	Advanced vehicle lighting systems (e.g., DRL/Auto/Auto high beam / Adaptive headlights / Curve adaptive) Assessed to IIHS Headlight Test and Rating Protocol.	V	H-6	Medium	Now	21	5.3%	9	4.8%

4.1.7 Measures to address driver decision-making

Addressing driver decision-making is challenging. Effective countermeasures are those that focus on enhancing the driver's ability to make appropriately safe decisions.

Driver performance failures include driver decision errors as well as volitional driving acts (see *ECIS Report 1*); inattention is also classified as a driver performance failure. Within ECIS, driver decision errors included 'looked-but-failed-to-see' errors, as well as judgement / misinterpretation errors, and vehicle control errors (see *ECIS Report 3* for detail).

Driver error in the form of 'looked-but-failed-to-see' was a contributing factor to 20.3% of crashes (n = 81 of 400; MAIS 3+: 17.0%, n = 32 of 188). This factor was especially common in Across Path crashes (35.0%, n = 42 of 120). From a countermeasure perspective, advanced vehicle lighting systems would be applicable to 54 of these crashes (i.e., 13.5% of 400: MAIS 3+: 12.8%, n = 24 of 188) (Table 4.11).

Measures to address the failure to yield to traffic signs and traffic lights – seen in 20.5% of crashes (n = 82 of 400), whether this being in error or being intentional, are outlined below (Section 4.1.14, Section 4.3).

A range of countermeasures directed at *Threats to Normal Driving* would also play a role in *looked-but-fail-to-see* crashes; the reader is referred to Section 3.3 where relevant countermeasures are presented.

TABLE 4.11 MEASURES TO ADDRESS ELEMENTS OF DRIVER DECISION-MAKING

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Looked but failed to see vehicle or hazard / object (i.e., other road users, object) (Note: see below for further interventions to address LBFS)									
3-5	Advanced vehicle lighting systems (DRL / auto high beam / adaptive headlights)	V	H-6	Medium	Now	54	13.5%	24	12.8%
Risk factor: Failure to detect parked vehicle / objects on side of roadway (ECIS Case [A] driver)									
3-5	Object detection (including night vision assist & 360° surround view monitor with Head-Up Display (HUD)	V	H-6	High	Now	17	4.3%	2	1.1%
Risk factor: Unsafe margin, following too close									
3-5	Traffic management (congestion alert, hazard light alert)	V	H-6	Low	Now	18	4.5%	5	2.7%
3-5	Headway monitor / Following Distance Warning (advisory)	V	H-5	Medium	Now	31	7.8%	9	4.8%
5	Intervening Headway / Following Distance System	V	V-2	High	Short-term	31	7.8%	9	4.8%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.

Table 4.11 also highlights countermeasures to address drivers failing to detect parked vehicles (or other roadside objects) and drivers keeping an unsafe margin, or following distance, to the vehicle in front. These countermeasures provide information to drivers of the impending threat (e.g., object detection, insufficient headway) who then need to respond.

The Intervening Headway System actively increases the distance to the vehicle in front as the time-to-collision (TTC) falls below a safe threshold value, although this is more conservative than the AEB TTC threshold. Intervening headway systems that exercise throttle control and/or braking are under development. Intervening Headway systems differ from AEB as the application occurs well before an emergency scenario emerges; integrating these systems with congestion alert and DMS / OSM will likely increase their value even further. These systems are primarily relevant to the prevention of Rear Impact crashes. These systems are separate to adaptive cruise control functionality and are 'always-on.'

4.1.8 Measures to address other aberrant driver behaviour

Within the ECIS, a small number of crashes occurred due to aberrant behaviour (see Table 4.12). Measures to address these at present rely on police enforcement, with future vehicle technology providing alerts in real-time. The efficacy of these alerts would be heavily influenced by driver intentionality.

TABLE 4.12 MEASURES TO ADDRESS OTHER ABERRANT BEHAVIOURS

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Driving in incorrect direction (lane/enter opposite carriageway incorrectly)									
3-5	In-vehicle wrong-way alert	V	H-5	Medium	Short-term	4	1.0%	4	2.1%
Risk factor: Intentional improper use of emergency lane									
3-5	Alert on improper lane use	V	H-5	Low	Medium-term	0	0.0%	0	0.0%
Risk factor: Improper (intentional) use of opposing lane									
3-5	Police enforcement / interception [a]	D	H-3	High#	Now	4	1.0%	4	2.1%
3-5	In-vehicle lane direction warning system (wrong direction alert) [b]	V	H-5	Low	Short-term	4	1.0%	4	2.1%
Risk factor: Criminal activity and/or reckless driving									
3-5	Police enforcement (intercept) & removal from road [a]	D	H-3	High	Now	15	3.8%	10	5.3%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
a. Efficacy rating dependent upon presence and interception by police. Future systems may be able to automatically inform police of the location of the vehicle, dependent on other technology integration.
b. Future systems may be able to intervene by depowering the vehicle and/or exercising complete takeover of the vehicle bringing it to a stop, noting that this capability is dependent on integration with other active safety systems.

4.1.9 Measures to address the use of cruise control and its impact on crashes

While cruise control was active for 17 ECIS case drivers, in 13 instances its use played a contributory role for the occurrence of the crash and/or the severity of injury sustained, equating to 3.3% of all crashes (i.e., n = 13 of 400); all but two were Lane Departure crashes.

As shown in *ECIS Report 3*, driver use of cruise control played a contributing role to the crash by:

1. Drivers setting the cruise control above the speed limit with disregard to route-based advisory speed signs.
2. Cruise control being active when the driver was drowsy and/or fell asleep.
3. Drivers were not attending fully to the driving task.

From a countermeasure perspective (Table 4.13), advanced adaptive cruise control systems combined with Attention Assist would be efficacious in mitigating some, but not all, of these scenarios. Adaptive Cruise Control systems that link with other in-vehicle systems, such as ISA, DMS-OSM-based Attention Assist, Forward Collision Warning (FCW) and Object Detection technologies, would likely be a high efficacy countermeasure in addressing this crash factor. This interlinked suite of technologies will be most suited to managing *Deviations from Normal Driving* and the further progression of the driver toward a state where the crash is unavoidable.

TABLE 4.13 MEASURES TO ADDRESS USE OF CRUISE CONTROL

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Cruise control active and apparent failure to respond to intersection / correct lane deviation									
3-5	Adaptive cruise control (ACC) [with Stop-Go & Traffic Jam Assist plus Steer/Collision Evade Assist]	V, S	V-2	Medium	Medium -term	11	2.8%	5	2.7%
Risk factor: Cruise control active and assessed to be contributing factor for crash event and/or associated with injury severity (ECIS Case [A] driver)									
3-5	Disengage to correct vehicle speed (comply, advisory), with driver warning based on road environment, link to speed sign recognition / ISA	V, S	H-6	High	Medium -term	4	1.0%	2	1.1%
3-5	Disengage cruise control linked to Attention Assist, using DMS / OSM	V, S	H-6	High	Medium -term	11	2.8%	5	2.7%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.

4.1.10 Measures to address driver manoeuvres and other driver actions

There were a number of driver/vehicle movements that each resulted in a small proportion of crashes, all of which would be sensitive to specific in-vehicle technology countermeasures (see Table 4.14). For the crashes in their field of influence, these measures would have medium-to-high efficacy, some of which will only become available in the short-to-medium term.

TABLE 4.14 MEASURES TO ADDRESS DRIVER MANOEUVRES AND OTHER ACTIONS

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Reversing and fail to look/see (ECIS Case [A] driver)									
3-5	Rear Cross-Traffic Alert (RCTA) / collision warning (inclusive of autobrake / rear-AEB)[63,64]	V	H-6	Medium	Short-term	1	0.3%		0.0%
Risk factor: Vehicle without driver - driver exiting vehicle (ECIS Case [A] driver)									
3-5	Vehicle park system / Park-brake warning (door open, belt off)	V	H-6	Medium	Short-term	1	0.3%	1	0.5%
Risk factor: Turning against traffic (e.g., U-turn) (ECIS Case [A] driver)									
3-5	Blind Spot Monitoring (BSM) warning	V	H-6	Medium	Now	2	0.5%	2	1.1%
Risk factor: Encounter prior crash on road									
3-5	Crash notification system, in-vehicle alert (V2V)	V	V-2	Medium	Medium-term	1	0.3%	1	0.5%
Risk factor: Non-responsive driver: Uncontrolled vehicle in reverse gear / moving backwards (ECIS Case [A] driver)									
3-5	Rear-AEB - Autobrake	V	V-2	High	Short-term	2	0.5%	1	0.5%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.

63 For information on implementation of reverse detection systems, see: UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e

64 IIHS. Evidence mounts for effectiveness of rear autobrake. 2021. https://www.iihs.org/news/detail/evidence-mounts-for-effectiveness-of-rear-autobrake. See also: IIHS. Compendium of HLDI collision avoidance research. HLDI Bulletin Vol. 37, No. 12: December 2020. https://www.iihs.org/media/e635cc76-b9bc-4bad-a30a-5d7b78791df2/vxeQ3A/HLDI%20Research/Collisions%20avoidance%20features/37-12-compendium.pdf

4.1.11 Measures focussed on vehicle braking systems

As the crash situation moves to a *Critical Situation* (Phase 5) vehicle braking systems can play a vital role in crash prevention. These systems can also play a role in mitigating injury severity by reducing vehicle impact speed, and hence the reducing the magnitude of kinetic energy drivers are exposed to in crashes (see Phase 7, *Crash*).

It is useful when discussing the sophistication of vehicle braking systems fitted to vehicles involved in ECIS crashes to note that approximately half of the vehicles applied the brakes pre-crash, with the time under braking being small (refer to *ECIS Reports 1 and 2*). None of the vehicles had Autonomous Emergency Braking (AEB) systems fitted; hence where braking did occur it was due to driver action alone.

When compared against available braking technology,[65] most of the vehicles involved in the ECIS crashes had a suboptimal braking system. This is reflected by 93.8% of crash-involved vehicles not having the combination of Emergency Brake Assist (EBA), Anti-lock Braking System (ABS) and Electronic Brake Force Distribution (EBD) fitted (n= 375 of 400; MAIS 3+, n = 179, 95.5%).

These braking technologies are important as they are the basis upon which Autonomous Emergency Braking (AEB) functions. It is also the case that driver responses to Forward Collision Warning (FCW) and automated vehicle responses to Object Detection Systems, Cross-Traffic Alert and Collision Evade Assist, among others, rely on highly sophisticated and optimised braking systems.

Table 4.15 presents the fitment gap for these braking systems. These systems are rated as having high efficacy as while they are dependent on driver response, they are highly efficacious when braking is applied both with respect to crash avoidance and injury mitigation due to speed reductions achieved at impact.

TABLE 4.15 MEASURES TO ADDRESS SUBOPTIMAL VEHICLE BRAKING SYSTEMS

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Braking system suboptimal (Note: systems not fitted, crash sensitive)									
3-5	Emergency brake assist (EBA)[66]	V	V-2	High*	Now	314	78.5%	161	85.6%
3-5	Anti-lock braking system (ABS)[67]	V	V-2	High*	Now	194	48.5%	100	53.2%
3-5	Electronic Brake Force Distribution (EBD)	V	V-2	High*	Now	296	74.0%	150	79.8%

* Efficacy is high when used, but crash avoidance is dependent on timely brake use, while injury mitigation potential is dependent upon speed reduction achieved, hence, the time from brake application to collision becomes the key determinant of effect (see text).

65 ABS, BA, EBD were all available prior to 2014, this being the commencement of the ECIS program; the assessment of suboptimal was made on this basis and all three systems not being fitted.
66 Fitment into passenger vehicles required under Australian Design Rule (ADR) 89: https://www.legislation.gov.au/Details/F2017L01221
67 Fitment into passenger vehicles required under Australian Design Rule (ADR) 31 https://www.legislation.gov.au/Details/F2017L01221 and ADR 35: https://www.legislation.gov.au/Details/F2022L00213

4.1.12 Measures to address driver response to the establishment of a shared forward collision path

Once vehicles are on a collision trajectory, the countermeasure objective is to bring the drivers back to a state of *Normal Driving* from the now established *Emerging Situation* (Phase 4) or *Critical Situation* (Phase 5). This reversion to *Normal Driving* (Phase 2) can only be achieved through braking and/or steering avoidance by one or both involved drivers, as appropriate.

While collision avoidance is the primary objective when vehicles enter a shared collision trajectory, it is recognised that injury mitigation through the reduction of impact speed may be the only plausible outcome that can be achieved in some instances. This occurs when the time-to-collision (TTC) is very short (0.5 - 1 s) and the time for a driver to respond effectively, or for an automatic braking system to be completely efficacious, is more limited; such scenarios can be conceptualised as occurring late in Phase 5 of the ISC. Notwithstanding this, relevant countermeasures are placed in the pre-crash phase of the ISC, reflecting their first point of influence on the crash. Indeed, collision warnings are likely to occur in the *Emerging Situation (Phase 4)* of the ISC.

Forward Collision Warning (FCW) and Autonomous Emergency Braking (AEB) have emerged as key safety technologies.[68] This has led to the implementation of vehicle safety standards in relation to AEB[69] and inclusion into the NCAP test protocol and scoring criteria.[70] Evidence of the high efficacy for AEB is growing,[71,72,73] although evidence for AEB efficacy for midblock head-on crashes is more limited (see below). The injury reduction benefit of AEB has also been demonstrated among drivers requiring hospitalisation following a crash[74] as has the impact of speed limit reductions on crash outcomes, given braking occurred. [75] FCW has also been shown to be highly efficacious in some scenarios, although is rated here as having medium efficacy due to the requirement for driver response (see below).

Newer emerging technologies include Motorcycle AEB (MAEB)[76], Collision Evade Assist and Rear Impact Alert (for the vehicle to be struck); the efficacy of these emerging technologies is not currently known.

Table 4.16 presents five applicable countermeasures. None of the vehicles involved in the ECIS crashes had these technologies fitted. Emphasis is placed on the discussion of FCW and AEB due to their current availability.

- Forward Collision Warning (FCW).
    - FCW systems recognise an impending threat by mapping the trajectory of the vehicle and the time-to-collision with another vehicle. FCW is available now and provides an audio-visual warning and requires drivers to respond to the emerging threat. These systems are applicable to vehicle-to-vehicle collision scenarios.
    - Vehicle-to-vehicle frontal impact (i.e., forward striking) conflict was seen in 67% of driver injury crashes (n = 268 of 400) and in-principle is applicable to all of these crashes.
        - Includes Lane Departure crashes (Section 4.3), Across Path crashes (Section 4.4) and Rear Impact crashes (Section 4.5) where the forward path of vehicles aligned in the crash.
    - FCW is rated as having a medium efficacy, on average, with respect to crash prevention as it relies on driver response following recognition of a scenario where opposing vehicles have a

68 FCW and AEB were introduced to certain vehicle models as early as 2000 in Europe and the United States.
69 Fitment into passenger vehicles required under Australian Design Rule (ADR) 98: https://www.legislation.gov.au/Details/F2021L01519. Similar regulations are in effect overseas, see for example: UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e
70 https://www.euroncap.com/en/vehicle-safety/the-ratings-explained/safety-assist/aeb-car-to-car/
71 Sander U. Opportunities and limitations for intersection collision intervention—A study of real world 'left turn across path accidents. Accident Analysis & Prevention. 2017;99:342-55.
72 Scanlon JM, Sherony R, Gabler HC. Injury mitigation estimates for an intersection driver assistance system in straight crossing path crashes in the United States. Traffic Injury Prevention. 2017;18(sup1):S9-S17.
73 Bareiss M, Scanlon J, Sherony R, Gabler HC. Crash and injury prevention estimates for intersection driver assistance systems in left turn across path/opposite direction crashes in the United States. Traffic Injury Prevention. 2019;20(sup1):S133-S8. FCW also can be highly effective.
74 Lee S, Jeong E, Oh C, Lee G. Estimation of the Safety Benefits of AEBS Based on an Analysis of the Korean In-Depth Accident Study (KIDAS) Database. KSCE Journal of Civil Engineering. 2019;23(12):5208-14. Note: of up to 25% based on the Injury Severity Score; the KIDAS study design is very similar to ECIS.
75 ECIS Report 2 modelled the influence of earlier speed limit reductions, hence lower impact speed, on crash outcomes.
76 MAEB is an appliable countermeasure for two crashes (0.5%) that involved a motorcycle having a frontal impact with the driver side of an ECIS case driver vehicle. Note: Performance testing of Car-to-Motorcycle AEB is commencing in 2023 in NCAP protocols (see 'What's New from 2023' and '2023 Tests, Scores & Weightings' Fact sheets at https://www.ancap.com.au/media-and-gallery/media-releases/bbe2af.

shared travel trajectory, that if left uncorrected, a collision will occur. An injury mitigation benefit also applies where speed reduction occurs pre-crash due to driver response and subsequent braking and/or steering avoidance actions.

- Acknowledging the physical geometry of intersections, a medium efficacy rating for FCW in these environments remains applicable due to the relatively lower speeds of vehicles at intersections (as seen in ECIS data). These lower speeds can offset, or counteract, the potential limitations of vehicle-to-vehicle recognition achieved by radar systems in these environments, noting that research has pointed to the relatively limited negative influence of sightline obstructions in these environments, for instance.[77] The same principle applies to AEB in relation to intersection crashes, however the efficacy is rated as high due to the intervention being automatic and not subject to a driver response.
- In relation to midblock frontal (i.e., head-on) crashes, the longer physical distance and hence time-to-collision – despite generally higher travel speeds - plays a key role in vehicle detection. That this was common to the ECIS crashes, based on crash reconstruction, is reflected in the efficacy ratings of FCW and AEB. It is acknowledged that evaluations of these technologies in this crash scenario is needed.
- It is expected that any limitations of FCW vehicle recognition systems be completely overcome by V2V communication and predictive collision algorithms in the future.[52]

- Autonomous Emergency Braking (AEB)
  - AEB is an especially important braking system which automatically intervenes when the driver fails to act. AEB has both a crash prevention and injury mitigation function. AEB acts to automatically decelerate a vehicle once it approaches or is within the outer acceptable margin of the threshold time-to-collision (TTC) window with another vehicle in the forward direction. Throttle deceleration and braking is applied as part of the AEB function.
  - AEB has multiple sub-types. These AEB sub-types are optimised to specific crash scenarios including Junction AEB for the management of intersection crashes, as well as high-speed AEB, among others.[78]
  - Applicable to 67% of driver injury crashes (n = 268 of 400) and available now, AEB has a projected high efficacy rating (≥ 50%) for the crashes examined (see notes below Table 4.16).
  - The high efficacy rating for AEB is based on[79]:
    - All vehicles involved in the crash have AEB fitted.
    - All vehicles have advanced high efficacy braking systems fitted.
    - All vehicles are fitted with multiple sensor systems capable of vehicle recognition in all weather and lighting conditions.
  - It is highly probably that future AEB systems will have sensor systems supported by V2V and V2I communication technologies, thereby ensuring AEB is a high efficacy countermeasure; this integration is expected to occur over the short-to-medium term.

Other future-oriented systems such as Collision Evade Assist linked to Driver Monitoring technologies and Rear Collision Alert are also noted. These systems will more than likely include autonomous braking functions. The success of Collison Evade Assist depends on 'escape and evasion' path for the relevant vehicle to avoid a collision, which would be dependent on the road geometry, surrounding traffic and infrastructure.

The implementation of these technologies is dependent upon advanced braking systems and sophisticated collision-object detection sensing algorithms that are currently under development.[80] As indicated, V2V communication technologies will play a crucial role in the functional performance of these systems and driver responses in the future.[81] Once implemented, it is expected these systems will play a crucial role in resolving

77 Bareiss M, Gabler HC, Sherony R. Considering real-world sightline obstructions in crash and injury prevention estimates for left turn across path/opposite direction intersection active safety systems. Traffic Injury Prevention. 2020;21(sup1):S102-S6. Note: TTC beyond 1 second seen to translate to >55% crash reduction for frontal MAIS 2+ crashes and beyond 1.5 s TTC for all frontal crashes.

78 See: '2023 Tests, Scores & Weightings' Fact sheet at https://www.ancap.com.au/media-and-gallery/media-releases/bbe2af.

79 See references provided here. Further evaluation research to confirm these efficacy levels in relation to crash avoidance and injury mitigation is recommended, noting however these systems are already subject to regulatory action and NCAP testing (i.e., AEB).

80 Zhang L, Gao J, Lan L, Li B. Sun H. Cooperative collision warning system design at intersections based on trajectory prediction and conflict risk evaluation. International Journal of Vehicle Design. 2021; 87.

81 Marshall D, Wu X, Brown T, Boyle LN. Connected vehicle alerts: one size doesn't fit all scenarios. Transportation Research Board 96th Annual Meeting, Washington DC.

vehicle-to-vehicle conflicts and ensuring a return to *Normal Driving,* with the effect that crashes are prevented. Where complete collision avoidance does not occur, it is highly likely that injury severity will be lower due to moderated vehicle speeds at impact (see Phase 7, Crash).

TABLE 4.16 MEASURES TO ADDRESS FORWARD COLLISIONS

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: On collision trajectory#									
3-5	Forward collision warning (FCW, camera, radar, LiDAR)†	V	H-6	Medium[a b]	Now	268	67.0%	121	64.4%
3-5	Autonomous Emergency Braking[82] (AEB) – includes consideration of subtypes (e.g., junction AEB, high-speed AEB) (includes throttle management by definition)	V	V-2	High[a]	Now	268	67.0%	121	64.4%
3-5	Motorcycle AEB (MAEB), for vehicle-to-motorcycle collisions	V	V-2	Medium	Short-term	2	0.5%	2	1.1%
3-5	Autonomous Emergency Steer / Collision Evade Assist	V	V-2	High	Medium -term	268	67.0%	121	64.4%
3-5	Autonomous Emergency Steer / Collision Evade Assist linked to DMS/OSM for non-responsive drivers	V	V-2	High	Medium -term	40	10.0%	20	10.6%
3-5	Rear collision alert, with rear impact detection (Note: for struck vehicle, all rear impact crash types; AEB relevant)	V	H-6	Low	Short-term	69	17.3%	14	7.4%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
# Collision path required; includes vehicle-to-vehicle collisions, excludes single vehicle run-off-road crashes.
a. Efficacy ratings reflects the estimated average effect across frontal impact crashes where both involved vehicles are fitted with the technology, or the striking vehicle for rear-impact crashes. The expected efficacy ratings are based on the outcomes of performance tests and published literature, applied to the ECIS crashes where a frontal impact occurred. These ratings are higher than some crash population-based efficacy studies that report claim frequency, changes in medical costs, or broad crash benefits at the population level due to the specificity of applicable crashes to which the technology applies. Further real-world evaluations required to confirm efficacy; refer to discussion and references provided in the text above.
b. Efficacy rating is independent of drivers' ability to respond; i.e., independent of driver state and health contributing factors and impairment contributing factors that would act to negatively impact a driver response to a FCW alert.

82 Fitment into passenger vehicles required under Australian Design Rule (ADR) 98: https://www.legislation.gov.au/Details/F2021L01519. Similar regulations are in effect overseas, see for example: UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e

4.1.13 Measures to address vehicles moving outside their travel lane

The unintended or uncontrolled movement of a vehicle beyond the centre lane and then outside the bounds of its travel lane requires immediate correction. That this movement occurs is a function of one or more of the upstream *Threat to Normal Driving* factors and/or those associated with *Deviations from Normal Driving* (Phase 3).

Relevant crashes include single vehicle run-off road crashes, multiple vehicle-to-vehicle head-on crashes, and rear impact crashes, whether these occur in traffic or a vehicle colliding with a parked vehicle (or object on the road, e.g., builders skip/bin). These crashes represent 55.5% (n = 222 of 400) of the ECIS sample. The injury severity of these crashes was high, with 62.8% of ECIS drivers sustaining MAIS 3+ injuries (n = 118 of 188). For percent values expressed as a function of Lane Departure crashes, refer to Section 4.2.

Countermeasures to address vehicle deviations from the lane include (Table 4.17):

- Lane Departure Warning (LDW).
- Automated Lane Keep Assist (ALKS) and extensions linked to DMS-OSM to recognise and manage non-responsive drivers (Emergency LKA, ELKS).
- Tactile line markings.

The primary function of these countermeasures is to achieve correction of the vehicle movement. Except for the high efficacy intervening (automated) LKA system, LDW and tactile line markings are designed to warn a driver who then must act to correct the lane deviation. Given the functional features of current devices, LDW and ALKS are applicable to 85.1% (n = 189 of 222) of crashes where a vehicle departed its lane; this accounts for 47.3% of injured drivers (189 of 400) and 53.7% drivers who sustained MAIS 3+ injuries (n = 101 of 188).

The installation of audio tactile and highly visible lane centre-line markings is applicable to 30.3% of crashes (n = 121 of 400; MAIS 3+: 37.2%, n = 70 of 188), while installation of these markings on the left side and right side of the vehicle given its direction of travel are applicable to 18.5% (n = 74 of 400) and 9.0% (36 of 400) of crashes, respectively.

Managing vehicle loss of control – Loss of control causing a vehicle to depart its lane was associated with 16.8% (n = 67 of 400) crashes. These crashes were classified as sensitive to ESC given the crash location, movement of the vehicle and the function of ESC. ESC was not fitted to the relevant vehicle in 92.5% (n = 62 of 67) of these loss of control events and therefore is the primary vehicle countermeasure to address this contributory factor. The fitment of ESC would be a safety benefit to 15.5% of hospitalised drivers (n = 62 of 400).

Managing the condition of the road shoulder – The condition of the roadside shoulder was classified as poor in 114 crashes, equating to 28.5% of the total crash trauma; this was a factor in 32.4% of MAIS 3+ injured drivers (n = 61 of 188). Rectification was feasible at 76.3% (n = 87 of 114) of relevant locations, or for 21.8% of ECIS case drivers. Rectification works include sealing, extending, and flattening the shoulder, covering or protection of drains/channels, and the elimination of rollover tripping hazards. Correction of these deficiencies is a high efficacy measure that will also potentiate the benefit of ESC and technology measures.

TABLE 4.17 MEASURES TO ADDRESS VEHICLES MOVING BEYOND THEIR TRAVEL LANE

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Vehicle deviated (departed) from lane / beyond centre of lane (Note: not keeping in lane)									
3-5	Lane departure warning (LDW, acoustic, haptic) (Note: excludes unpaved roads, single lane roads)	V	H-6	Medium[83]	Now	189	47.3%	101	53.7%
3-5	Automated Lane Keep Assist (ALKS): intervening for oncoming traffic crash mitigation	V	V-2	High[84] [85]	Now	189	47.3%	101	53.7%
3-5	Emergency Lane Keep Assist (ELKS) to manage non-responsive drivers (intervening, linked to DMS/OSM)	V	V-2	High	Medium-term	60	15.0%	32	17.0%
3-5	Audio Tactile Lane Markings (ATLM) with centre line Raised Reflective Pavement Markers (RRPMs) / Rumble strips (absent)	R	R	Medium	Now	121	30.3%	70	37.2%
3-5	ATLM with RRPMs / Rumble strips: left side (absent)	R	R	Medium	Now	74	18.5%	43	22.9%
3-5	ATLM with RRPMs / Rumble strips: right side (absent)	R	R	Medium	Now	36	9.0%	22	11.7%
Risk factor Loss of control causing departure from lane (i.e., out of control, not overtaking)									
3-5	Electronic Stability Control (ESC), includes traction control[a,b]	V	V-2	Medium	Now	62	15.5%	29	15.4%
Risk factors: Condition of shoulder poor									
3-5	Seal / extend shoulder, remove objects, rollover trip hazards, protect drains; assessed as feasible[c]	R	R	High	Now	87	21.8%	51	27.1%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
a. Fitment into passenger vehicles required under Australian Design Rule (ADR) 88, https://www.legislation.gov.au/Details/F2017L01229
b. Excludes vehicles where ESC installed.
c. Feasible based on available physical space.

83 Dean M., Riexinger L. Estimating the Real-World Benefits of Lane Departure Warning and Lane Keeping Assist," SAE Technical Paper 2022-01-0816, 2022.
84 Sternlund S, Strandroth J, Rizzi M, Lie A, Tingvall C. The effectiveness of lane departure warning systems—A reduction in real-world passenger car injury crashes. Traffic Injury Prevention. 2017;18(2):225-9.
85 ALKS / LKA also under purview of UN GSR and NCAP test protocol.

4.1.14 Measures to address driver decisions to enter intersections that lead to vehicles being on a collision trajectory

The failure to yield at an intersection due to unintended (i.e., error) or intentional disregard or non-response to a traffic sign/signal and/or the presence of another vehicle(s) was seen in 38.0% of crashes (n = 152 of 400; MAIS 3+: 33.5%, n = 63 of 188). These relate to all drivers injured in Across Path crashes (n = 120) [see Section 4.3 for % values] and a subset of drivers injured in Rear Impact crashes (n = 23) [see Section 4.4 for % values].

As outlined in detail in *ECIS Report 3*, this contributing factor can be disaggregated as:

- Driver error at intersection, including judgement errors and 'looked-but-fail-to-see' errors (12.5%, n = 50 of 400; MAIS 3+: 11.2%, n = 21 of 188).
- Driver failed to obey a traffic sign, including a red light (19.8%, n = 79 of 400; MAIS 3+: 19.7%, n = 37 of 188).
    - Failed to obey a red light (8.3%, n = 33 of 400; MAIS 3+: 7.4%, n = 14 of 188).
- Driver failed to recognise intersection and/or changing conditions at intersection (5.5%, n = 22 of 400; MAIS 3+: 2.7%, n = 5 of 188); these were all Rear Impact crashes.

A range of infrastructure countermeasures aimed at supporting or forcing an appropriate and safe decision by the driver to be made are presented in Table 4.18. The identified countermeasures can be categorised into four groups:

1. Improved delineation of the intersection, via signage, perceptual countermeasures, or structural additions including horizontal and vertical deflection treatments.
2. Changes to traffic signs associated with intersection centreline hardening (e.g., splitter island, rubber curbs, bollards) to reduce turning speed and ensure turn occurs at a right angle by preventing diagonal entry movements at intersections).
3. Installation or changes to traffic signals, including the installation of red light (speed) cameras.
4. Physical modifications to the roadway (i.e., by the addition of lanes to facilitate safe merging and passing of vehicles, turning off carriageways etc.).

The proportion of crashes to which these countermeasures are applicable is presented in Table 4.18, as are relevant 'qualifiers. An assessment of the feasibility of adopting each measure at each site in the context of the specific behaviour seen in ECIS crashes was made. Site feasibility included traffic volume, surrounding land use, and space availability. Installation of these measures assumes optimal positioning with respect to the driver.

Key measures based on having high efficacy and the proportion of crashes the countermeasure is applicable to are:

- Vertical deflection (19.8%, n = 79 of 400).
- Advance warning signs on approach to intersection (12.3%, n = 49 of 400).
- Improve delineation of intersection (perceptual measures, in and lead up to) (12.0%, n = 48 of 400).
- Centreline hardening of intersection (Stop-sign already present) (12.8%, n = 51 of 400). This includes physical measures to promote/ensure appropriate turn angle and lower speeds.
- Intersection hardening with Stop Sign to replace Give Way sign (11.0%, n = 44 of 400).
- Install red-light camera (address red light running, improve compliance) (14.8%, n = 59 of 400).

For completeness, it is noted that vehicle-based countermeasures have a major role to play in influencing and ensuring driver safety at intersections. These are described fully in Section 4.3.

TABLE 4.18 MEASURES TO ADDRESS DRIVER DECISIONS TO ENTER INTERSECTIONS

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) N	MAIS 3+ (N = 188) %
Improved delineation of the intersection									
3-5	Advance warning signs of intersection	R	R	Medium	Now	49	12.3%	22	11.7%
3-5	Improved delineation of intersection (perceptual measures, in and lead up to)	R	R	Medium	Now	48	12.0%	20	10.6%
3-5	Horizontal deflection (chicane) (speed calming, decision support] [qualifier: feasible / not]	R, S	R	Medium	Now	14	3.5%	8	4.3%
3-5	Vertical deflection: raised platform, extended hump (speed calming, decision support)	R, S	R	Medium	Now	79	19.8%	37	19.7%
3-5	Centreline hardening of intersection (Stop-sign already present)	R	R	Medium	Now	51	12.8%	24	12.8%
3-5	Improve lighting at intersection (night / dark / dusk / dawn; no lights / lights off leading to poor visibility)	R	R	Medium	Now	18	4.5%	8	4.3%
Changes to traffic signs with centreline hardening									
3-5	Intersection centreline hardening with Stop sign (replace Give Way sign)	R	R	Medium	Now	44	11.0%	21	11.2%
3-5	Introduce 4-way Stop, with supporting perceptual measures to 'force' yield (replace give-way) (address fail to see, fail to yield behaviour	R	R	High	Now	7	1.8%	3	1.6%
Installation or changes to traffic lights									
3-5	Install traffic lights[86] (+/- sensory warning, e.g., red-light blanket, inclusive of improved delineation and centreline hardening)	R	R	High	Now	29	7.3%	12	6.4%
3-5	Install red-light camera (address red light running, improve compliance)	R	R	Medium	Now	59	14.8%	22	11.7%
3-5	Hold red light - Intelligent traffic light phasing (vehicle sensitive) (to address fail to comply, recognise or driver error)	R	R	Medium	Now	17	4.3%	4	2.1%
Structural changes: lane additions / modifications									
3-5	Install dedicated right turn arrows	R	R	High	Now	19	4.8%	10	5.3%
3-5	Install far right merge lane, for turn across crashes	R	R	High	Now	1	0.3%	0	0.0%
3-5	Install left merge onto lane, for turn onto carriageway crashes	R	R	High	Now	7	1.8%	3	1.6%
3-5	Install / fix dedicated left turn lane, to address turn off carriageway crashes	R	R	High	Now	1	0.3%	1	0.5%
3-5	Install dedicated right turn lane (Note: links to Michigan Left and 'Crash' phase measures, e.g., Side Road Activated Speed [SRAS] system, perceptual measures; see *Section 5.3)*	R	R	High	Now	10	2.5%	3	1.6%

86 Intersection type: Local with Local Road: n = 17, 56.7%; Local with MABC road: n = 10, 33.3%; B road with C road: n = 2, 6.7%; Arterial Road with Arterial Road: n = 1, 3.3%.

4.2 MEASURES SPECIFIC TO LANE DEPARTURE CRASHES

Half (50.5%, n = 202 of 400) of all drivers enrolled to ECIS were injured in Lane Departure crashes, of which 57.4% (n = 116 of 202) sustained MAIS 3+ injuries. Drivers injured in Lane Departure crashes accounted for 61.7% of all MAIS 3+ injured drivers. Crashes involved a single vehicle leaving the road to the left or to the right, and vehicle-to-vehicle head-on impacts on a curve or straight section of road. Details pertaining to these drivers and these crashes can be found in *ECIS Reports 1, 2 and 3.*

Countermeasures applicable to Lane Departure crashes are presented in Table 4.19 and Table 4.20. The percent values reflect the proportion of Lane Departure crashes where each countermeasure is applicable. These countermeasures were described in detail above (Section 4.1.13).

These data highlight the critical safety measures required to prevent Lane Departure crashes. These include currently available medium and high efficacy measures. Vehicle systems that do not require a driver response have high efficacy, while infrastructure solutions benefit driver awareness and decision making and provide for opportunity to the driver(s) to return to *Normal Driving*. Given the complexity of factors associated with Lane Departure crashes and the different types of vehicle movements, multiple active vehicle safety system and infrastructure measures will be required for these crashes to be successfully prevented.

TABLE 4.19 MEASURES TO ADDRESS LANE DEPARTURE CRASHES: MEASURES TO PREVENT AND CORRECT VEHICLE MOVEMENTS BEYOND THE LANE

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡∞	Horizon	MAIS 1+ (N = 202)		MAIS 3+ (N = 116)	
						N	%	N	%
Risk factor: Vehicle deviated (departed) from lane / beyond centre of lane									
3-5	Lane departure warning (LDW, acoustic, haptic) (Note: excludes unpaved roads, single lane roads)	V	H-6	Medium	Now	175	86.6%	99	85.3%
3-5	Automated Lane Keep Assist (ALKS): intervening for oncoming traffic crash mitigation[87]	V	H-6	High	Now	175	86.6%	99	85.3%
3-5	Emergency Lane Keep Assist (ELKS) to manage non-responsive drivers (intervening, linked to DMS/OSM)	V	V-2	High	Medium -term	54	26.7%	30	25.9%
3-5	Tactile lane markings: centre line RRPM / Rumble strips (absent)	R	R	Medium	Now	117	57.9%	68	58.6%
3-5	Audio Tactile Lane Markings (ATLM) with centre line RRPM / Rumble strips (absent)	R	R	Medium	Now	69	34.2%	42	36.2%
3-5	ATLM with RRPMs / Rumble strips: left side (absent)	R	R	Medium	Now	36	17.8%	22	19.0%
Risk factor: Vehicle or object in forward path given vehicle trajectory due to lane deviation									
3-5	Forward collision warning (FCW, camera, radar, LiDAR)[a]	V	H-6	Medium	Now	74	36.6%	52	44.8%
Risk factor Loss of control causing departure from lane (i.e., out of control, not overtaking)									
3-5	Electronic Stability Control (ESC), includes traction control[b]	V	V-2	Medium[88]	Now	61	30.2%	29	25.0%
Risk factors: Condition of shoulder poor									
3-5	Seal / extend shoulder, remove objects, rollover trip hazards, protect drains; assessed as feasible[c]	R	R	High	Now	85	42.1%	50	43.1%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
∞ Refer to relevant references provided in Tables above.
Note: a. excludes single vehicle run-off-road crashes; b. Excludes vehicles where ESC installed; c. feasible based on available physical space.

87 Per UN Regulation UN Regulation No. 157 - Automated Lane Keeping Systems (ALKS).
88 Webb, C. Estimating lives saved by electronic stability control, 2010–2014. Traffic Safety Facts Research Note. Report No. DOT HS 812 277). Washington, DC: National Highway Traffic Safety Administration; 2016.

TABLE 4.20 MEASURES TO ADDRESS LANE DEPARTURE CRASHES: COLLISION ALERT AND BRAKING SYSTEMS

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡∞	Horizon	MAIS 1+ (N = 202) N	MAIS 1+ (N = 202) %	MAIS 3+ (N = 116) N	MAIS 3+ (N = 116) %
Risk factor: Braking system suboptimal (Note: systems not fitted, crash sensitive)									
3-5	Emergency Brake Assist (EBA)	V	V-2	High*	Now	161	79.7%	97	83.6%
3-5	Anti-lock Braking System (ABS)	V	V-2	High*	Now	90	44.6%	53	45.7%
3-5	Electronic Brake Force Distribution (EBD)	V	V-2	High*	Now	151	74.8%	89	76.7%
Risk factor: On collision trajectory# (Note: excludes run-off-road crashes)									
3-5	Autonomous Emergency Braking[89] (AEB) – inclusive of subtypes (e.g., junction AEB, high-speed AEB) (includes throttle management by definition)	V	V-2	High[a]	Now	74	36.6%	52	44.8%
3-5	Autonomous Emergency Steer / Collision Evade Assist	V	V-2	High	Medium -term	74	36.6%	52	44.8%
3-5	Autonomous Emergency Steer / Collision Evade Assist linked to DMS/OSM for non-responsive drivers	V	V-2	High	Medium -term	16	7.9%	11	9.5%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
∞ Refer to relevant references provided in Tables above.
* Efficacy is high when used, but crash avoidance is dependent on timely brake use, while injury mitigation potential is dependent upon speed reduction achieved, hence, the time from brake application to collision becomes the key determinant of effect (see text Section 4.1.11).
# Collision path required; includes vehicle-to-vehicle collisions, excludes single vehicle run-off-road crashes.
a. Efficacy ratings reflects the estimated average effect across frontal impact crashes where both involved vehicles are fitted with the technology, or the striking vehicle for rear-impact crashes. The expected efficacy ratings are based on the outcomes of performance tests and published literature, applied to the ECIS crashes where a frontal impact occurred. These ratings are higher than some crash population-based efficacy studies that report claim frequency, changes in medical costs, or broad crash benefits at the population level due to the specificity of applicable crashes to which the technology applies. Further real-world evaluations required to confirm efficacy; refer to discussion and references provided in the text above.

89 Fitment into passenger vehicles required under Australian Design Rule (ADR) 98: https://www.legislation.gov.au/Details/F2021L01519. Similar regulations are in effect overseas, see for example: UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e

4.3 MEASURES SPECIFIC TO ACROSS-PATH CRASHES

Drivers injured in Across Path crashes represent 30.0% (n = 120 of 400) of the ECIS sample. Of these, 44.2% (n = 53) sustained MAIS 3+ severity injuries, accounting for 28.2% of the 188 MAIS 3+ injured drivers in the ECIS study. All of these Across Path crashes occurred at an intersection.

Three Across Path crash sub-types were defined: enter carriageway; turn across; cross-traffic; further distinction was made between locations with traffic lights and those without (see Appendix B, Figure B.1).

Tables 4.21, 4.22 and 4.23 present the active vehicle safety systems and infrastructure measures identified as being applicable to manage the consequences of driver decisions — intentional or in error — as well as the vehicle movements that follow. The number and percent values in these Tables reflect the total number of Across Path crashes.

Central to these crashes was a driver failing to yield to another vehicle, either through intentional or unintentional disregard of a traffic sign/light, or through error. This mix is reflected below.

- Driver error at intersection, including judgement errors and 'looked-but-fail-to-see' errors (33.3%, n = 40 of 120; MAIS 3+: 30.2%, n = 16 of 53).
- Driver failed to obey a traffic sign, including a red light (65.8%, n = 79 of 120; MAIS 3+: 69.8%, n = 37 of 53).
    - Failed to obey a red light (27.5%, n = 33 of 120; MAIS 3+: 26.4%, n = 14 of 53).

The identified countermeasures have specific roles and are therefore relevant to specific driver actions and vehicle movement. Countermeasures are grouped as follows:

- Countermeasures presented in Table 4.21 outline infrastructure measures designed to influence driver decision-making. These include measures that improve the delineation of the intersection; measures that aim to induce drivers to stop before entering the intersection, and the addition or modification of lanes to reduce the opportunity for conflict.
- Countermeasures presented in Table 4.22 outline active vehicle safety systems that warn and intervene to prevent the driver either entering the intersection and/or preventing vehicle collisions. Also included is the installation of red-light camera technology to address red-light running.
- Countermeasures presented in Table 4.23 outline vehicle braking technologies necessary for drivers to execute the required critical response, or failing this, to provide the necessary platform for relevant technologies to intervene when the driver does not (i.e., AEB). These 'base' braking systems are required for key intervening technologies, including for instance Active Brake Assist with cross-traffic function.

It is important to bear in mind that the choice of countermeasure(s) solutions is dependent on the Across Path crash sub-type and the movement being addressed. This is especially the case when considering infrastructure treatments. However, it is clear that measures to induce vertical deflection are key, with this being applicable (and feasible) to 63.3% of Across Path crashes. This measure supports decision-making in addition to acting as a speed calming measure. Other perceptual countermeasures and intersection hardening have high applicability (see Table 4.21).

Measures to induce compliance with traffic lights are important, given that 27.3% of Across Path crashes involved a driver illegally breaching a red light. The installation of red-light cameras is an important countermeasure, noting that red-light cameras were nominated as being necessary at selected sites where the installation of traffic lights was required.

Existing and future active vehicle safety systems represent critical countermeasures to address Across Path crashes (Table 4.22). These measures include FCW (all crashes), Cross Traffic Alert and Active Brake Assist with cross traffic function (both applicable to 64.2% of Across Path crashes), as well as other supportive warning-based systems. Similarly, although AEB is a vital measure most vehicles had suboptimal braking systems (Table 4.23).

The data highlight a wide range of countermeasures required to address Across Path crashes. Common to all is the need to address driver behaviour. The application of infrastructure-based measures to induce behavioural change through design is imperative. This is particularly important given that the active safety systems which are likely to play a critical role in addressing these types of crashes have been developed only recently. Given the slow vehicle turnover rate in Victoria, these technologies are unlikely to fully penetrate the vehicle fleet until up to 29 years in the future (see Section 9.1 for a discussion of this point).

TABLE 4.21 MEASURES TO ADDRESS ACROSS PATH CRASHES: INFRASTRUCTURE MEASURES TO ADDRESS DRIVER DECISION-MAKING

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 120) N	MAIS 1+ %	MAIS 3+ (N = 53) N	MAIS 3+ %
Improved delineation of the intersection									
3-5	Advance warning signs of intersection	R	R	Medium	Now	39	32.5%	19	35.8%
3-5	Improve delineation of intersection (perceptual measures, in and lead up to)	R	R	Medium	Now	38	31.7%	18	34.0%
3-5	Horizontal deflection (chicane) (speed calming, decision support] [qualifier: feasible / not]	R, S	R	Medium	Now	12	10.0%	8	15.1%
3-5	Vertical deflection: raised platform, extended hump (speed calming, decision support)	R, S	R	Medium	Now	76	63.3%	37	69.8%
3-5	Centreline hardening of intersection (Stop-sign already present)	R	R	Medium	Now	47	39.2%	23	43.4%
3-5	Improve lighting at intersection (night / dark / dusk / dawn; no lights / lights off leading to poor visibility)	R	R	Medium	Now	17	14.2%	8	15.1%
Changes to traffic signs with centreline hardening									
3-5	Intersection centreline hardening with Stop Sign (replace Give Way sign)	R	R	Medium	Now	40	33.3%	20	37.7%
3-5	Introduce 4-way Stop, with supporting perceptual measures to 'force' yield (replace Give-Way sign) (address fail to see, fail to yield behaviour)	R	R	High	Now	7	5.8%	3	5.7%
Installation or changes to traffic lights									
3-5	Install traffic lights (+/- sensory warning, e.g., red-light blanket, inclusive of improved delineation and centreline hardening)[90]	R	R	High	Now	29	24.2%	12	22.6%
3-5	Install red-light camera (address red light running / improve compliance; includes where traffic lights newly installed [n = 23], where hold red/turn arrow installed [n=5], and where already installed to address non-compliance [n = 26] [volume-based, not local street intersections]	R	R	Medium	Now	54	45.0%	21	39.6%
3-5	Hold red light - Intelligent traffic light phasing (vehicle sensitive) (to address fail to comply, recognise or driver error)	R	R	Medium	Now	17	14.2%	4	7.5%
Structural changes: lane additions / modifications									
3-5	Install dedicated right turn arrows	R	R	High	Now	19	15.8%	10	18.9%
3-5	Install far right merge lane, for turn across crashes	R	R	High	Now	1	0.8%	0	0.0%
3-5	Install left merge onto lane, for turn onto carriageway crashes	R	R	High	Now	7	5.8%	3	5.7%
3-5	Install / fix dedicated left turn lane, to address turn off carriageway crashes	R	R	High	Now	0	0.0%	0	0.0%
3-5	Install dedicated right turn lane (Note: links to Michigan Left and 'Crash' phase measures, e.g., Side Road Activated Speed [SRAS] systems, perceptual measures; see *Section 5.3)*	R	R	High	Now	6	5.0%	1	1.9%

Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 120); MAIS 3+ (N = 53)

90 Intersection type: Local with Local Road: n = 17, 56.7%; Local with MABC road: n = 10, 33.3%; B road with C road: n = 2, 6.7%.

TABLE 4.22 MEASURES TO ADDRESS ACROSS PATH CRASHES: VEHICLE TECHNOLOGY MEASURES

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡ ∞	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 120) N	%	MAIS 3+ (N = 53) N	%
Risk factor: Vehicle moving across path, travelling straight through intersection									
3-5	Forward Collision Warning (FCW) (intersections; low-med-high speed, with narrow time-to-collision (TTC) window) (vehicle driving through intersection)	V	H-6	Medium	Now	120	100%	53	100%
Risk factor: Apparent failure to see / recognise /obey traffic signs at intersection (i.e., traffic signal, Stop sign, Give Way sign)									
3-5	Traffic light alert (advisory, V2I)	V	H-5	Medium	Now	33	27.5%	14	26.4%
3-5	Traffic sign display (in-vehicle)	V	H-5	Medium	Now	46	38.3%	23	43.4%
Risk factor: Failure to recognise changed traffic signals (traffic lights)									
3-5	Lead-vehicle start alert, to address rear impact collision at traffic light	V	H-6	Low	Short-term	33	27.5%	14	26.4%
Risk factor: Enter intersection across path of vehicle [subset of Types F, H; refer Appendix B]									
3-5	Cross Traffic Alert (collision warning, on vehicle intersection [prevent]	V	H-6	Medium	Now	77	64.2%	38	71.7%
3-5	Active Brake Assist with cross-traffic function / Junction AEB (optimised with sensor based on V2V not yet available)‡	V	H-6	High	Short-term	77	64.2%	38	71.7%
Risk factor: Turn across path of oncoming vehicle in intersection [subset of Type G; refer Appendix B]									
3-5	Turn Assist (collision) warning (intersections) / Right turn crash warning (in intersection and turning)	V	H-6	Medium	Now	43	35.8%	15	28.3%
Risk factor: Driver failed to obey a red light at intersection, entered									
3-5	Traffic sign warning and braking (brakes applied at red light to prevent entry against signal)	V	V-2	High	Medium-term	33	27.5%	14	26.4%
3-5	Intelligent Traffic Light Assist (haptic feedback of accelerator pushback + braking, V2V / V2I)	V	V-2	High	Medium-term	33	27.5%	14	26.4%
3-5	Install red-light camera[a]	R	R	Medium	Now	26	21.7%	11	20.8%
Risk factor: Drift / roll into intersection (from stationary) (ECIS Case [A] driver)									
3-5	Brake-hold with roll warning; applies brake in event of uncontrolled roll with link to DMS-OSM to assess for non-responsive drivers	V	H-6	Medium	Medium-term	3	2.5%	3	5.7%
3-5	Autobrake – forward (linked to DMS-OSM for non-responsive drivers)	V	V-2	High	Medium-term	3	2.5%	3	5.7%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
∞ Refer to relevant references provided in Tables above.
a. Red-light camera installed where feasible, based on road class / traffic volume (arterial roads).

TABLE 4.23 MEASURES TO ADDRESS ACROSS PATH CRASHES: COLLISION ALERT AND BRAKING SYSTEMS

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡∞	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 120) N	MAIS 1+ (N = 120) %	MAIS 3+ (N = 53) N	MAIS 3+ (N = 53) %
Risk factor: Braking system suboptimal (Note: systems not fitted, crash sensitive)									
3-5	Emergency Brake Assist (EBA)	V	V-2	High*	Now	96	80.0%	48	90.6%
3-5	Anti-lock Braking System (ABS)	V	V-2	High*	Now	67	55.8%	36	67.9%
3-5	Electronic Brake Force Distribution (EBD)	V	V-2	High*	Now	90	75.0%	44	83.0%
Risk factor: On collision trajectory# (i.e., excludes run-off-road, two crashes involving motorcyclists, and crashes classified as 'Other')									
3-5	Autonomous Emergency Braking[91] (AEB) – inclusive of subtypes (e.g., junction AEB, high-speed AEB) (includes throttle management)	V	V-2	High[a]	Now	119	99.2%	52	98.1%
3-5	Motorcycle AEB (MAEB), for vehicle-to-motorcycle collisions†	V	V-2	Medium	Short-term	1	0.8%	1	1.9%
3-5	Autonomous Emergency Steer / Collision Evade Assist	V	V-2	High	Medium-term	119†	99.2%	52	98.1%
3-5	Autonomous Emergency Steer / Collision Evade Assist linked to DMS/OSM for non-responsive drivers	V	V-2	High	Medium-term	8	6.7%	5	9.4%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
∞ Refer to relevant references provided in Tables above.
Collision path required; includes vehicle-to-vehicle collisions, excludes single vehicle run-off-road crashes.
* Efficacy is high when used, but crash avoidance is dependent on timely brake use, while injury mitigation potential is dependent upon speed reduction achieved, hence, the time from brake application to collision becomes the key determinant of effect (see text Section 4.1.11).
a. Efficacy ratings reflects the estimated average effect across frontal impact crashes where both involved vehicles are fitted with the technology, or the striking vehicle for rear-impact crashes. The expected efficacy ratings are based on the outcomes of performance tests and published literature, applied to the ECIS crashes where a frontal impact occurred. These ratings are higher than some crash population-based efficacy studies that report claim frequency, changes in medical costs, or broad crash benefits at the population level due to the specificity of applicable crashes to which the technology applies. Further real-world evaluations required to confirm efficacy; refer to discussion and references provided in the text above.
† MAEB is the powered two-wheeler (PTW) vehicle relevant countermeasure; Autonomous Emergency Steer / Collision Evade Assist not applicable to PTW vehicles.

91 Fitment into passenger vehicles required under Australian Design Rule (ADR) 98: https://www.legislation.gov.au/Details/F2021L01519. Similar regulations are in effect overseas, see for example: UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e

4.4 MEASURES SPECIFIC TO REAR IMPACT CRASHES

Drivers injured in Rear Impact crashes represented 17.3% (n = 69 of 400) of the ECIS sample, with 20.3% (n = 14) of these drivers sustaining MAIS 3+ injuries; these drivers accounted for 7.4% of all drivers with MAIS 3+ injuries.

Three Rear Impact subtypes were defined:

1. Impact involving a parked vehicle at a midblock location, including occupied and unoccupied vehicles.
2. Impact at an intersection, where traffic was either stationary or moving.
3. Impact in a midblock, where the traffic was either stationary or moving.

The countermeasures identified in Tables 4.24, 4.25 and 4.26 address specific aspects of driver decision making and actions and if left uncorrected a crash will inevitably occur. Due to the range of factors, there are multiple countermeasures applicable. Key findings are as follows.

- Forward Collision Warning (striking vehicle) and Rear Collision Alert (struck vehicle) are applicable for vehicles involved in each Rear Impact crash (100%, n = 69 of 69).
- For crashes where a vehicle struck a parked vehicle, Object Detection Systems are applicable to 24.5% of Rear Impact crashes (n = 17 of 69).
- Following too close was a key risk factor, seen in 42.0% (n = 29 of 69) of Rear Impact crashes. While congestion alerts through in-vehicle traffic management systems would be of value, Headway Monitor Systems offering warnings and escalating to intervening to manage driver headway distance represent a high efficacy countermeasure once available.
- 29.0% (n = 20 of 69) of Rear Impact crashes occurred following a vehicle departing its travel lane. LDW, ALKS and related systems, and tactile line markings are applicable countermeasures, although not in each case (Table 4.23). ESC was applicable to a single crash (1.4%); related to the need to correct the condition of the roadside shoulder.[92]
- Braking systems were deficient, with key braking technologies not fitted (i.e., EBA, EBS, ABS) (see Table 4.25). These systems enable a return to *Normal Driving*, either through the response of the driver or the automatic intervention of the braking system itself, via AEB. Advanced systems, such as Collision Evade Assist have the potential to map and execute an ‘escape and evade’ path and resume control to the driver when safe to do so; this has high value in managing the safety of non-response drivers (i.e., asleep, acute medical event). The fitment of these high efficacy countermeasures is a high priority for the prevention of these crashes.
- With Rear Impact crashes occurring at intersection locations, intersection specific countermeasures were also applicable (see Table 4.26). These measures relate to improving the delineation of the intersection, intersection hardening, the installation of traffic lights and a red-light camera where appropriate, and physical lane modifications. These measures are aimed at addressing driver error, the failure to recognise the intersection itself, and to improve compliance with yield requirements.

Based on the analysis of Rear Impact crashes, once drivers move though the *Emerging Situation* (Phase 4) toward the *Critical Situation* (Phase 5), active vehicle safety systems can play a central role in assisting the driver to recognise the impending collision threat and encourage and/or force by way of intervention a return to *Normal Driving* (Phase 2). These systems rely on primary braking systems which were found to be largely absent in the crash-involved vehicles in the ECIS sample. Infrastructure countermeasures can play a supporting role. These measures need to be focussed on improving driver decision-making by ensuring that intersection and lane boundaries are clearly delineated, adequate advanced warning of intersections is provided, and traffic flow is consistent. Systematic implementation of these countermeasures is necessary to achieve reductions in the number of drivers and other vehicle occupants injured in Rear Impact crashes.

92 Headway Monitor is separate and independent of cruise control systems.

TABLE 4.24 MEASURES TO ADDRESS REAR IMPACT CRASHES: VEHICLE TECHNOLOGY AND INFRASTRUCTURE MEASURES TO PREVENT AND/OR MITIGATE SPECIFIC MOVEMENTS

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡∞	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 69) N	%	MAIS 3+ (N = 14) N	%
Risk factor: On collision trajectory									
3-5	Forward Collision Warning (FCW)	V	H-6	Medium	Now	69	100%	14	100%
3-5	Rear Collision Alert, with rear impact detection (Note: for struck vehicle, all rear impact crash types; AEB relevant)	V	H-6	Medium	Now	69	100%	14	100%
Risk factor: Failure to detect parked vehicle / objects on side of roadway (ECIS Case [A] driver)									
3-5	Object detection (including night vision assist & 360° surround view monitor with Head-Up Display (HUD)	V	H-6	High	Now	17	24.6%	2	14.3%
Risk factor: Unsafe margin, following too close									
3-5	Traffic management (congestion alert, hazard light alert)	V	H-6	Low	Now	29	42.0%	8	57.1%
3-5	Headway monitor / Following Distance Warning (advisory)	V	H-5	Medium	Now	29	42.0%	8	57.1%
5	Intervening Headway / Following Distance System	V	V-2	High	Short-term	29	42.0%	8	57.1%
Risk factor: Vehicle deviated (departed) from lane / beyond centre of lane									
3-5	Lane Departure Warning (LDW, acoustic, haptic) (Note: excludes unpaved roads, single lane roads)	V	H-6	Medium	Now	14	20.3%	2	14.3%
3-5	Automated Lane Keep Assist (ALKS) (Note: excludes unpaved roads, single lane roads)	V	H-6	High	Now	14	20.3%	2	14.3%
3-5	Emergency Lane Keep Assist (ELKS) to manage non-responsive drivers (intervening, linked to DMS/OSM)	V	V-2	High	Medium-term	6	8.7%	2	14.3%
3-5	Audio Tactile Lane Markings (ATLM) with centre line RRPM / Rumble strips (absent)	R	R	Medium	Now	3	4.3%	2	14.3%
3-5	ATLM with RRPMs / Rumble strips: left side (absent)	R	R	Medium	Now	5	7.2%	1	7.1%
Risk factor Loss of control causing departure from lane (i.e., out of control, not overtaking)									
3-5	Electronic Stability Control (ESC)[a]	V	V-2	Medium	Now	1	1.4%	0	0.0%
Risk factors: Condition of shoulder poor									
3-5	Seal / extend shoulder to remove vehicle from roadway / lane abutment; assessed as feasible[b]	R	R	High	Now	1	1.4%	0	0.0%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
∞ Refer to relevant references provided in Tables above.
a. Excludes vehicles where ESC installed; b. feasible based on available physical space.

TABLE 4.25 REAR IMPACT CRASHES: MEASURES TO ADDRESS SUBOPTIMAL VEHICLE BRAKING SYSTEMS

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy‡∞	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 69) N	%	MAIS 3+ (N = 14) N	%
Risk factor: Braking system suboptimal (Note: systems not fitted, crash sensitive)									
3-5	Emergency Brake Assist (EBA)	V	V-2	High*	Now	49	71.0%	12	85.7%
3-5	Anti-lock Braking System (ABS)	V	V-2	High*	Now	31	44.9%	8	57.1%
3-5	Electronic Brake Force Distribution (EBD)	V	V-2	High*	Now	46	66.7%	12	85.7%
Risk factor: On collision trajectory#									
3-5	Autonomous Emergency Braking[93] (AEB) – inclusive of subtypes (e.g., junction AEB, high-speed AEB) (includes throttle management)	V	V-2	High[a]	Now	69	100%	14	100%
3-5	Autonomous Emergency Steer / Collision Evade Assist	V	V-2	High	Medium -term	69	100%	14	100%
3-5	Autonomous Emergency Steer / Collision Evade Assist linked to DMS/OSM for non-responsive drivers	V	V-2	High	Medium -term	14	20.3%	2	14.3%

‡ Efficacy estimated for future measures; evaluation of countermeasure effect will be required.
∞ Refer to relevant references provided in Tables above.
* Efficacy is high when used, but crash avoidance is dependent on timely brake use, while injury mitigation potential is dependent upon speed reduction achieved, hence, the time from brake application to collision becomes the key determinant of effect (see text Section 4.1.11).
\# Collision path required; includes vehicle-to-vehicle collisions, excludes single vehicle run-off-road crashes.
* Efficacy is high when used, but crash avoidance is dependent on timely brake use, while injury mitigation potential is dependent upon speed reduction achieved, hence, the time from brake application to collision becomes the key determinant of effect (see text Section 4.1.11).
a. Efficacy ratings reflects the estimated average effect across frontal impact crashes where both involved vehicles are fitted with the technology, or the striking vehicle for rear-impact crashes. The expected efficacy ratings are based on the outcomes of performance tests and published literature, applied to the ECIS crashes where a frontal impact occurred. These ratings are higher than some crash population-based efficacy studies that report claim frequency, changes in medical costs, or broad crash benefits at the population level due to the specificity of applicable crashes to which the technology applies. Further real-world evaluations required to confirm efficacy; refer to discussion and references provided in the text above.

93 Fitment into passenger vehicles required under Australian Design Rule (ADR) 98: https://www.legislation.gov.au/Details/F2021L01519. Similar regulations are in effect overseas, see for example: UN ECE. Revision of the EU General Safety Regulation and Pedestrian Safety Regulation. Informal document GRSP-63-31 (63rd GRSP, 14-18 May 2018 Agenda item 26(a)). https://unece.org › doc › wp29grsp › GRSP-63-31e

TABLE 4.26 MEASURES TO ADDRESS REAR IMPACT CRASHES: INTERSECTION SPECIFIC INFRASTRUCTURE MEASURES TO ADDRESS DRIVER DECISION-MAKING

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 69) N	MAIS 1+ (N = 69) %	MAIS 3+ (N = 14) N	MAIS 3+ (N = 14) %
Improved delineation of the intersection									
3-5	Advance warning signs of intersection	R	R	Medium	Now	9	13.0%	3	21.4%
3-5	Improve delineation of intersection (perceptual measures, in and lead up to)	R	R	Medium	Now	9	13.0%	2	14.3%
3-5	Horizontal deflection (chicane) (speed calming, decision support] [qualifier: feasible / not]	R, S	R	Medium	Now	1	1.4%	0	0.0%
3-5	Vertical deflection: raised platform, extended hump (speed calming, decision support)	R, S	R	Medium	Now	2	2.9%	0	0.0%
3-5	Centreline hardening of intersection (Stop-sign already present)	R	R	Medium	Now	3	4.3%	1	7.1%
3-5	Improve lighting at intersection (night / dark / dusk / dawn; no lights / lights off leading to poor visibility)	R	R	Medium	Now	1	1.4%	0	0.0%
Changes to traffic signs with hardening									
3-5	Intersection centreline hardening with Stop Sign (replace Give Way sign)	R	R	Medium	Now	3	4.3%	1	7.1%
Installation or changes to traffic lights									
3-5	Install traffic lights (+/- sensory warning, e.g., red-light blanket, inclusive of improved delineation and centreline hardening)[94]	R	R	High	Now	1	1.4%	0	0.0%
3-5	Install red-light camera (address red light running / improve compliance)	R	R	Medium	Now	5	7.2%	1	7.1%
Structural changes: lane additions / modifications									
3-5	Install / fix dedicated left turn lane, to address turn off carriageway crashes	R	R	High	Now	1	1.4%	1	7.1%
3-5	Install dedicated right turn lane (Note: links to Michigan Left and 'Crash' phase measures, e.g., Side Road Activated Speed [SRAS] systems, perceptual measures; see *Section 5.3)*	R	R	High	Now	3	4.3%	2	14.3%

94 Intersection type: Arterial Road with Arterial Road: n = 1, 3.3%.

5 RESULTS – MEASURES TO MANAGE CRASH ENERGY AND INJURY SEVERITY

Having been unable to prevent the progression towards the crash (Phases 3, 4, 5) and return to a *Normal Driving* state (Phase 2), the crash becomes inevitable. It is at this point that the time-to-collision is so short that prevention of the crash is no longer possible.

In the immediate moments prior to the crash (Phase 6), the focus is on vehicle impact preparatory measures. These measures include the priming of occupant protection measures to maximise their injury reduction benefit.

Once the crash occurs the countermeasure priority shifts to one of energy reduction, energy management (i.e., dissipation) and the mitigation of injury (Phase 7). Here, the role of the vehicle in protecting occupants is fundamental; this is achieved through vehicle design and passive safety features, such as airbags. Managing crash energy and minimising the energy transfer to occupants becomes the goal.

While the level of protection against injury provided by the vehicle is critical, the level of safety 'built in' to the road – or lack thereof – must also be addressed. Evidence of this need was presented in *ECIS Report 1* and *ECIS Report 2*, where the links between the level of safety provided by the vehicle, the road infrastructure settings inclusive of the speed limit, impact speed, and injury severity were demonstrated.

With this introduction in mind, this Section is focused on measures to manage crash energy and injury severity. The structure is as follows:

- Section 5.1: Measures common to all crash types -
  - Here the countermeasure intent is to address factors associated with injury severity including the level of protection against injury provided by the vehicle; the injury severity associated with specific impact configurations, and the management of impact speed. These measures are common to the three ECIS crash types (see below); cross-reference to these crash types is made as appropriate.
- Sections 5.2, 5.3, 5.4: Measures specific to Lane Departure crashes, Across Path crashes, and Rear Impact crashes respectively -
  - The countermeasure intent is to address the road and road infrastructure settings associated with injury severity specific to these crash types.
  - The identified countermeasures act by influencing the level of energy in the crash, either through reducing impact speed, modifying the angle of impact, reducing the likelihood of impacting rigid / fixed roadside objects, and managing the duration over which energy transfer occurs, as is seen in barrier systems. Similarly, addressing factors that exacerbate crash severity, such as rollover tripping factors and other factors associated with secondary impacts, is imperative.

The analysis of countermeasures presented here builds on *ECIS Reports 1 and 2* where evidence of the links between injury severity, vehicle safety and infrastructure settings were provided. *ECIS Report 3* provides a clear understanding of specific injury causation factors and represents the basis for the countermeasures presented here.

The countermeasures identified in the following section, like those in previous sections of this Report, are specific to the identified contributing factor. The percent (and number) presented in the following Tables reflects the proportion of drivers injured due, in part or in whole, to the identified factor. These crashes are said to be 'sensitive' to the identified countermeasure given its function and purpose; alternatively, the countermeasure is 'applicable' to the prevention and/or mitigation of these injuries.

5.1 MEASURES COMMON TO ALL CRASH TYPES

This section presents vehicle-based countermeasures focussed on preparation for the crash (Phase 6), measures to improve the level of protection provided by the vehicle and measures to achieve lower impact speeds. The measures are presented in Table form with a brief description of each as appropriate.

5.1.1 Immediate pre-crash injury mitigation measures

In the immediate moment prior to impact, vehicle 'pre-safe' systems function to optimise driver (occupant) seating position, optimise seat belt performance and prime airbag systems for rapid and optimal inflation.[67] Recognising the high noise level associated with airbag deployment, advanced systems emit a tone that ensures the eardrum is protected.

Other features include closing windows and the sunroof (if fitted) to prevent occupant ejection, brake pedal retraction and automatic entry post-crash to facilitate rapid extrication from the vehicle. Highly sophisticated systems can alter the seat position as well as the ride height of the vehicle. This aims to achieve a more optimal driver interaction with the airbag and to provide further protection from the leading edge of the impacting vehicle or object.

Base systems are available for all crash types, although their activation requires detection that a crash is imminent. This activation relies on sensor systems that link with active safety systems, such as FCW and AEB, as well as specific crash detection sensors (e.g., those that detect rapid deceleration, rear impact crash, rollover detection) and other vehicle intelligence (e.g., brake force detection).

These preparatory measures are relevant to all crash types (Table 5.1). Side impact pre-safe systems are applicable only to vehicle-to-vehicle crashes where the initial point of impact is the side of the vehicle, and more specifically, where the impact occurs in the proximity of the occupant compartment. Based on the ECIS program data, side impact pre-safe systems are applicable to 17% of injured drivers (n = 68 of 400; MAIS 3+: 18.6%, n = 35 of 188). The proportion of crashes sensitive to the side impact pre-safe system is 88.3% when limiting the analysis to drivers injured in countermeasure-relevant side impact vehicle-to-vehicle impacts (n = 68 of 77); all but one — classified as 'Other' — of these crashes were classified as Across Path crashes that occurred at intersections.

Given the likely potentiating effect of these systems on in-vehicle passive safety occupant protection measures, they are rated as having medium efficacy. Further research is needed to quantify this benefit.

TABLE 5.1 IMMEDIATE PRE-CRASH VEHICLE SAFETY OCCUPANT PROTECTION FOCUSSED MEASURES

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy‡	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Inevitable crash									
6	Pre-safe pre-crash systems[95]	V	V-1	Medium	Now	400	100%	188	100%
6	Side impact pre-safe systems[96]	V	V-1	Medium	Now	68	17.0%	35	18.6%

‡. Benefit stems from optimising the position of the driver to better facilitate the protection offered by passive safety systems (e.g., airbags, seat belt position, seat position). Exemplar system: https://emercedesbenz.com/autos/mercedes-benz/corporate-news/mercedes-benz-pre-safe-has-changed-the-world-of-driving/

95 Schoeneburg R, Fehring M, Richert J, Glashagel M, Ruf J, Walz M, Bogenrieder R, Feese J. Effectiveness Potential of PRE-SAFE® Impulse Using the Scenario of a Major Accident at an Intersection as an Example, Paper Number 17-0252. 25th ESV Conference Proceedings The 25th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Detroit, Michigan USA, June 2017.

96 Schoneburg R., Paurevic M., Fehring M., Richert J., Bogenrieder R. Evaluation of occupant protection systems: from a preventive to a pre-impacting restraint system, Paper Number 15-0374. Paper presented at the 24th Technical Conference on the Enhanced Safety of Vehicles (ESV), Gothenburg, Sweden, June 2015.

5.1.2 Improving vehicle safety and enhancing the level of protection against injury

'Crashworthiness' is the ability of a vehicle to manage the energy of the crash and protect the driver and occupants of vehicles from injury. As described in *ECIS Report 1*, the built-in 'safety envelope' of the vehicle is the upper margin of crashworthiness. It is beyond this point – referenced against impact speed – that the vehicle can no longer manage the crash energy and protect its occupants from serious injury.

Crashworthiness is assessed by the *New Car Assessment Program* (NCAP) using star-ratings that are awarded based on the safety performance of the vehicle. How well the vehicle performs in protecting occupants from injury is assessed against specific crash test requirements outlined in a series of test protocol documents.[97]

Safety ratings range from 1-star to 5-stars, with 5-stars being the highest current safety rating available. Vehicles with a 5-star rating are equipped with front and side impact airbags, have advanced seat belt systems, and among other safety systems have a high level of crashworthiness achieved through advanced design, sophisticated use of alloys and build quality. Vehicles with lower ratings lack these safety systems and therefore manage the energy of the crash less well, have a lower safety envelope, and offer lower levels of protection against injury for a given impact speed in comparison to higher rated vehicles.

While the relationship between injury severity and vehicle safety is well established, *ECIS Reports 1, 2, and 3* further demonstrated this point by showing a clear association between the vehicle star-rating and MAIS 3+ injuries.[98] Being involved in a crash whilst driving a lower rated vehicle or driving a vehicle without key safety features due to its age — noting that Australian NCAP was established in 1993 — represents a clear risk factor for serious injury. The extent to which this risk factor is present, and the countermeasures to address this are described below. The identified countermeasures consider the vehicle factors associated with the crash (e.g., mechanical failure, tyre condition), as well as the severity of injuries sustained.

Countermeasures for three vehicle subgroups were identified based on (Table 5.2):

1. Age-based criteria, vehicles manufactured pre-1970[99], characterised as having very poor safety performance (no star-rating applicable).
    - Relevant to 1.0% of ECIS case drivers (n = 4 of 400; MAIS 3+: 0.5%, n = 1 of 188).
    - Applicable countermeasure:
        - Requirement for Club permit & associated permits, with annual roadworthiness certificate (RWC) with emphasis on seat belt fitment.
2. Vehicles with limited safety features and poor crashworthiness (vehicles manufactured 1970 - 1990).
    - Driven by 6.8% of ECIS Case drivers (n = 27 of 400; MAIS 3+: 8.0%, n = 15 of 188).
    - Applicable countermeasure:
        - New vehicle subsidy scheme, leading to vehicle replacement with a *Safe Pick*.
3. Vehicles with a star-rating lower than 3 (includes vehicles manufactured 1970 - 1990).
    - Driven by 25.0% of ECIS Case drivers (n = 100 of 400; MAIS 3+: 27.7%, n = 52 of 188).
    - Applicable countermeasure:
        - New vehicle subsidy scheme, leading to vehicle replacement with a *Safe Pick*.

The proportion of vehicles in these categories was comparable for drivers injured in Lane Departure crashes, Across Path crashes and Rear Impact crashes (see *ECIS Report 3* for detail).

97 The Used Car Safety Program (UCSR) similarly rates the safety of vehicles but using mass crash data as the basis for the determination of the vehicle safety rating, also expressed as a star-rating and a *Safe Pick*. The UCSR are calculated for all used cars on Australian roads annually https://howsafeisyourcar.com.au/

98 The importance of vehicle safety is further emphasised by 5-star vehicles being the key performance criteria for Safe Vehicles, this being one of the three elements that defines an inherently safe road transport system (see ECIS Report 1, Chapter 8).

99 These four vehicles were Special Interest Vehicles.

TABLE 5.2 MEASURES TO ADDRESS VEHICLES WITH POOR OCCUPANT PROTECTION AND LOW CRASHWORTHINESS

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy†	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Very poor safety performance of vehicle (pre-1970 year-of-manufacture)									
7	Club permit & associated permits (including street rod, as is required) / annual roadworthiness certificate (RWC)	V	H-3	Low	Now	4	1.0%	1	0.5%
Risk factor: Limited safety features and poor crashworthiness (1970-1990)									
7	New vehicle subsidy scheme [A-vehicle]	V	H-7	Medium	Now	27	6.8%	15	8.0%
7	New vehicle subsidy scheme [B-vehicle]	V	H-7	Medium	Now	9	2.3%	6	3.2%
7	New vehicle subsidy scheme [A & B-vehicle [A & B-vehicle, crash count, of n = 393]	V	H-7	Medium	Now	35	8.9%	20	9.8%
Risk factor: Vehicle with ANCAP rating <3 (ECIS Case [A] vehicle)									
7	New vehicle subsidy scheme [A]	V	H-7	Medium	Now	100	25.0%	52	27.7%
7	New vehicle subsidy scheme [B]	V	H-7	Medium	Now	63	15.8%	36	19.1%
7	New vehicle subsidy scheme [crash indicator]	V	H-7	Medium	Now	100	25.0%	52	27.7%

† Efficacy reflects the injury mitigation (safety) differential between the replaced vehicle and the subsequent 5-star vehicle, assuming no other factor changes in crash; likely a conservative estimate depending on age differential of vehicle, class of vehicle(s) and mass. Applicable for relevant vehicles only. Benefit needs to be formally assessed. No consideration given to cost-effectiveness of program given in this assessment, as not a consideration for countermeasures identified in this Report.

Considering the above, it is important to recognise the inferior safety performance of 3-star and 4-star safety rated vehicles — many of which have only frontal airbags (if any) — relative to 5-star vehicles. It is expected most of these vehicles would be replaced through natural attrition. Indeed, the achievement of an inherently safe road transport system is dependent upon this, with the future minimum vehicle safety standard being equivalent to that provided by a current 5-star rated vehicle. Here, it is useful to note that of the hospitalised drivers enrolled to the ECIS program, 22.5% (n = 90 of 400; MAIS 3+: 16.0%, n = 30 of 188) were driving a 5-star rated vehicle at the time of the crash.

Given the anticipated time taken for all vehicles in the passenger car fleet to be rated as having 5-star safety,[100] the need to implement infrastructure-based countermeasures aimed at eliminating serious injury, and to continue to work toward the achievement of the *Safe Driver,* is imperative.

100 Defined by current star-rating protocols.

5.1.3 Measures to address injury risk factors specific to crash impact configuration

While a single index of vehicle safety is commonly used, these measures – such as the NCAP star-rating[101] – are a composite score of the level of occupant protection provided by the vehicle to the occupant across different impact configurations. The level of protection is dependent on the passive safety measures and other aspects of vehicle design and how the vehicle is built.

Within the field of vehicle safety and impact biomechanics (i.e., the study of impact forces acting on the human body and resultant injuries), impact direction is categorized as follows:

- Frontal impact: the point of impact is the front of the vehicle.
- Side impact: the point of impact is the left or right side of the vehicle.
- Rear impact: the point of impact is the 'back' of the vehicle.
- Rollover impact / events: the vehicle tips on its side, at least ¼ turn (i.e., rests on its side, left or right).

The four impact configurations also have distinct sub-types, depending on the 'overlap' of the vehicle and the exact point of impact. These sub-types are important when identifying countermeasures. This is the case as the position of the driver relative to the point of impact, combined with the level of impact energy as determined by impact speed, for the most part determines type and severity of injuries sustained. The preservation of the occupant compartment is vital, as compromising the integrity of the safety cell through crush or deformation, can directly injure the driver. This can be further complicated in multiple impact crashes.

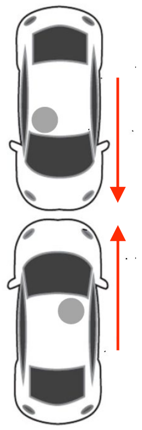
As noted earlier, all vehicles have an in-built safety envelope, which once breached can no longer protect the driver from serious injury (see also *ECIS Report 1*). This is the case even when vehicles are fitted with airbags, as the reduction in the occupant safety cell reduces their effectiveness, and the vehicle structure 'folds-into' the occupant. Injuries occur due to the direct application of force to the person's body at a level the body cannot withstand. Injuries can also occur due to inertial (i.e., non-contact) forces, which are commonly associated with lateral and rotational acceleration.

Understanding these different impact configurations and how injuries occur is important to identifying and prioritising injury prevention countermeasures. As these impact configurations can all occur within the three ECIS crash types, reference is made to these crash types only for context when discussing each impact configuration.

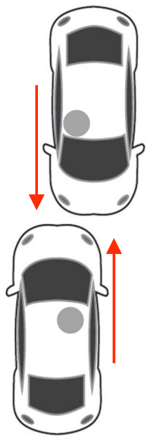
As per *ECIS Report 3*, pictograms are used in each subsection to show the impact configurations of interest. The red arrow within each pictogram denotes the direction of travel at impact, or in the case of vehicle rollover, that the vehicle rotated longitudinally (i.e., roll axis).

5.1.3.1 Addressing injury in frontal impact crashes

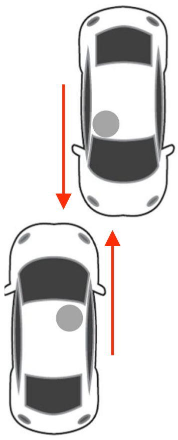
Frontal impact crashes were common, with 68.9% of ECIS case drivers (n = 275) experiencing one of the three types of impacts shown below.[102] Of these drivers, 46.9% (129 of 275) sustained MAIS 3+ injuries, accounting for 68.6% of drivers sustaining MAIS 3+ injuries (of 188). Frontal impact crashes were common in Lane Departure crashes (81.2%, n = 164 of 202) (see *ECIS Report 3* for detail).



Frontal impact: fully distributed
(>50% overlap)



Frontal impact: offset
(≤50% overlap)



Frontal impact: narrow offset
(≤15% overlap)

101 NCAP star-rating scores also assess the presence and effectiveness of active safety systems (i.e., Safety Assist), Vulnerable Road User (VRU) protection, in addition to adult and child occupant protection.
102 Red arrows indicate direction of vehicle movement.

Countermeasures to improve occupant safety in frontal impact crashes are as follows (Table 5.3):

- Application and revision of frontal crash protection regulations[103] (ADR 69[104], ADR 73[105]) with the aim of reducing lower extremity injury risk, and to account for the full range of vehicles in the Victorian vehicle fleet. Of note is that 11.3% of drivers injured in frontal impact crashes sustained MAIS 3+ lower extremity injuries, this being 34.9% of all drivers with MAIS 3+ injuries (n = 45 of 129).
- Frontal driver airbags, which were relevant to 17.5% of all injured drivers. This is a high efficacy countermeasure to address head, face, neck, and chest injuries, which were common in the absence of a frontal driver airbag (37.1%, n = 26 of 70).
- Implementation of a Narrow Frontal Offset crash test, common in overseas jurisdictions, has been shown to improve the safety of occupants through design changes to vehicles.[106] Narrow offset crashes accounted for 16.6% of all driver trauma (n = 66 of 400) and 25.5% (n = 70 of 275) of frontal impact crashes. These impacts have a high injury acuity, with 56.1% of drivers sustaining MAIS 3+ injuries (n = 37 of 66).
- Improved crashworthiness requirements to address excessive intrusion due to vehicle damage affected 31.5% of drivers involved in frontal impact crashes, with a high proportion of these drivers sustaining MAIS 3+ injuries (65.9%, n = 83 of 126). Impact speed, discussed below is a key measure here.
- Optimised seat design and seat belts.

TABLE 5.3 MEASURES TO IMPROVE FRONTAL IMPACT OCCUPANT PROTECTION[107]

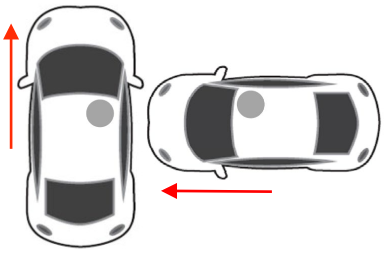
ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) N	MAIS 3+ (N = 188) %
Risk factor: Frontal impact crash – driver hospitalised									
7	Measures to improve frontal impact occupant protection[103], review of ADR69[104]/ADR73[105] for performance requirements	V	V-1	High	Now	275	68.8%	129	68.6%
Risk factor: Frontal impact crash – No frontal airbags fitted									
7	Frontal driver (advanced, dual inflation) airbags inclusive of seat belt optimisation	V	V-1	High	Now	70	17.5%	36	19.1%
7	Per above, to address MAIS 3+ head-face-neck (cervical) and chest injuries	V	V-1	High	Now	26	6.5%	26	13.8%
Risk factor: Frontal impact crash – Narrow frontal offset, with associated loss of compartment integrity									
7	Improved protection associated with Narrow Frontal Offset test[106]	V	V-1	High	Now	66	16.6%	37	19.7%
Risk factor: Frontal impact crash – Excessive intrusion associated with driver being trapped									
7	Improved structural crashworthiness: enhanced crash test matrix and stricter frontal crash protection standards	V	V-1	Medium	Now	126	31.5%	83	44.1%
7	Improved toe-pan design, including knee bolster and footwell airbags to address MAIS 3+ abdominal / lumbar spine / lower extremity / pelvis injuries	V	V-1	Medium	Now	49	12.3%	49	26.1%
Risk factor: Frontal impact, as single impact (damage) event only: Sub-optimal seat performance									
7	Optimised seat design and seat belts to address MAIS 2+ spine injuries	V	V-1	Medium	Now	42	10.5%	28	14.9%

103 Australian Design Rule (ADR) 69 and ADR 73 specify minimum safety performance standards for frontal impact crashes.
104 ADR 69 crash test specification: https://www.legislation.gov.au/Series/F2006L01455 (based on United States FMVSS 208).
105 ADR 73 crash test specification: https://www.legislation.gov.au/Series/F2005L03990 (as per United Nations Regulation No. 94).
106 Lund A. A brief history of the IIHS small overlap test. Global NCAP meeting. Brasilia, Brazil; 15-17 November 2015.
107 Safety benefits of frontal crash protection demonstrated by: Fitzharris, M., Fildes, B., Newstead, S., Logan, D. (2006). Crash-based evaluation of Australian Design Rule 69 (full frontal crash protection). Canberra: Australian Transport Safety Bureau. https://www.infrastructure.gov.au/roads/safety/publications/2006/pdf/Grant_Report200603.pdf

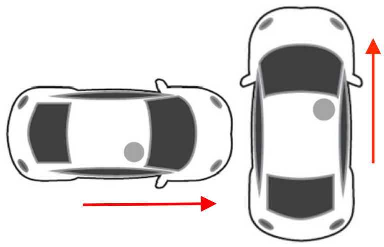
5.1.3.2 Addressing injury in side impact crashes

One-quarter of all crashes (25.0%, n = 100 of 400) involved a side impact crash. This crash configuration was more common for drivers involved in Across Path crashes (57.5%, n = 69 of 120). Half of all drivers involved in side impact crashes sustained MAIS 3+ injuries (i.e., 50 of 100).

The impact occurred either on the side of the vehicle closest to the driver (i.e., right, or near side) or to the opposite (left) side of the vehicle (i.e., far side; see below). Collisions where the impact occurred to the driver side of the vehicle were highly injurious.



Side impact: 'near-side' to driver



Side impact: 'far-side' to driver

Countermeasures to address injuries sustained in side impact crashes are as follows (Table 5.4):

- Head protecting side curtain airbag systems.
    - 64.0% (n = 64 of 100) of drivers involved in side impact crashes did not have a head protecting side airbag; these drivers represent 16.0% of all hospitalised drivers and 21.3% of drivers with MAIS 3+ injuries. One-quarter of these drivers sustained MAIS 3+ injuries of the head, face, or neck (23.4%, n = 15 of 64).
- Thorax (chest) protecting side impact airbags.
    - 60.0% (n = 60 of 100) of drivers involved in side impact crashes did not have a thorax (chest) protecting side airbag; these drivers represent 15.0% of all hospitalised drivers and 20.2% of drivers with MAIS 3+ injuries. More than half of these drivers sustained MAIS 3+ injuries of the head, face, or neck (60%, n = 36 of 60).
- Centre-airbags, to address the increased injury risk associated with driver-to-occupant contact.
    - Influencing 6.5% of all driver trauma, a centre airbag was applicable to 26% (n = 26 of 100) of side impact crashes.
- Optimisation of seat belt systems, to better control the occupant movement in near-side and far-side impact crashes.
    - Combined, this measure can influence the protection for 15.6% of drivers (i.e., 4.3% + 11.3%).
- Compliance with Australian Design Rules (ADR) 85. This recently implemented regulation addresses occupant protection in the event of impacts with poles (or trees).
    - Applicable to 5.3% of all driver trauma (MAIS 1+: n = 21 of 400) and 6.4% (n = 12 of 188) of MAIS 3+ driver trauma. The highly injurious nature of these crashes is indicated by 57.2% of these drivers sustaining MAIS 3+ injuries (n = 12 of 21).
- Revision of the side impact crash test, ADR 72, to account for vehicles of different geometry and mass to better reflect the current vehicle fleet.
    - Relevant to 19.3% of all driver trauma (n = 77 of 400; MAIS 3+: 20.2%, n = 38 of 188), 49.4% sustained MAIS 3+ injuries (n = 38 of 77). A high proportion of these drivers were trapped due to a high degree of structural deformation (63.6%, n = 49 of 77).

These countermeasures are specific to a subset of impact scenarios. Noting the medium-to-high efficacy of these countermeasures, and the high proportion of drivers sustaining MAIS 3+ injuries, these countermeasures have the capacity to reduce a sizeable proportion of serious injury trauma.

TABLE 5.4 MEASURES TO IMPROVE SIDE IMPACT OCCUPANT PROTECTION[108]

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Side impact airbag sensitive crash - no head protecting airbags									
7	Head protecting side curtain airbag (with seat belt optimisation, structural enhancements)	V	V-1	High	Now	64	16.0%	40	21.3%
7	Per above, to address MAIS 2+ head, face, neck, chest regions	V	V-1	High	Now	20	5.0%	15	8.0%
Side impact (left/right): Side impact airbag sensitive - No thorax (including combination, head) airbags									
7	Thorax protecting side airbags (with seat belt optimisation, structural enhancements)	V	V-1	High	Now	60	15.0%	38	20.2%
7	Per above, to address MAIS 2+ head, face, neck, chest regions	V	V-1	High	Now	50	12.5%	36	19.1%
Side impact (left/right): Side impact airbag sensitive, with front left passenger present									
7	Centre-airbag in vehicle (front-only)	V	V-1	High	Now	26	6.5%	11	5.9%
7	Per above, to address MAIS 2+ head, face, neck, chest regions	V	V-1	High	Now	15	3.8%	10	5.3%
7	Centre-airbag in vehicle (front-through-rear seats)	V	V-1	High	Now	28	7.0%	11	5.9%
7	Per above, to address MAIS 2+ head, face, neck, chest regions	V	V-1	High	Now	17	4.3%	10	5.3%
Side impact: impact to left side of vehicle ('far-side', to driver)									
7	Optimisation of restraint system to address MAIS 2+ head, face, neck (cervical) regions	V	V-1	Medium	Now	17	4.3%	7	3.7%
Side impact: impact to right side of vehicle ('near-side', to driver)									
7	Optimisation of restraint system to address MAIS 2+ head, face, neck (cervical) regions	V	V-1	Medium	Now	45	11.3%	36	19.1%
Side impact (left/right): Side impact airbag sensitive - impact with narrow object (tree, pole)									
7	Improved side impact protection / pole side impact test (ADR 85[109], ANCAP)	V	V-1	High	Now	21	5.3%	12	6.4%
Side impact (left/right): Side impact airbag sensitive - vehicle-vehicle impact (MVA), incompatible collision partner									
7	Improved side impact protection – expanded impact partner test battery to account for the range of vehicle mass and geometry in the vehicle fleet	V	V-1	Medium	Now	77	19.3%	38	20.2%
Side impact (left/right): Side impact airbag sensitive - vehicle-vehicle impact (MVA), excessive deformation									
7	Improved side impact protection (structural engineering): expanded impact partner test battery (mass, geometry) per ADR 72[110]	V	V-1	Medium	Now	77	19.3%	38	20.2%
7	Per above to address structural deformation (trapped)	V	V-1	Medium	Now	45	11.3%	29	15.4%

108 For comprehensive examination of side impact protection see: Fitzharris M, Stephan K. Assessment of the need for, and the likely benefits of, enhanced side impact protection in the form of a Pole Side Impact Global Technical Regulation. Monash University, 2013. http://www.infrastructure.gov.au/roads/publications/files/PSI_GTR_Report.pdf

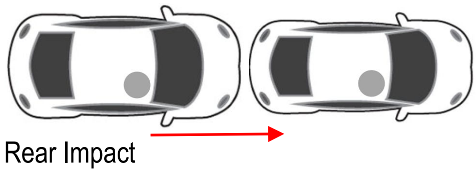
109 ADR 85 came into effect on 1 November 2017 for all new vehicle models and 1 November 2021 for all vehicles; specifies the minimum safety performance standards for pole side impact crashes. https://www.legislation.gov.au/Details/F2015L02109 (as per UN R. 135).

110 ADR 72 specifies specify minimum safety performance standards for side impact vehicle-to-vehicle crashes; see https://www.legislation.gov.au/Series/F2005L03992 (as per UN R. 95).

5.1.3.3 Addressing injury in rear impact crashes

Of the 400 ECIS case drivers, 69 (17.3%, of 400) were injured in a rear impact crash. ECIS case drivers were either in the 'striking' vehicle or the 'struck' vehicle, as follows:

- For the 'striking' driver, the collision point is the front of the vehicle and is therefore a frontal impact.
  - Accounts for 58.0% (n = 40) of drivers involved in 'Rear Impact' crashes, or 10.0% of drivers enrolled to the ECIS program (MAIS 3+: 2.1%, n = 4 of 188).
- For the 'struck' driver, the collision point is the back, or rear of the vehicle.
  - Accounts for 42.0% (n = 29) of drivers involved in 'Rear Impact' crashes, or 7.3% of drivers enrolled to the ECIS program (MAIS 3+: 5.3%, n = 10 of 188).



In addition to the frontal impact countermeasures relevant for drivers in the 'striking' vehicle, for the 'struck' vehicle (i.e., back of vehicle), two countermeasures were identified (see Table 5.5). These countermeasures are:

- Implementation of a rear impact crash test. At present, no such crash test is in effect in Australia.
- Optimisation of vehicle seats, with anti-whiplash protection measures; this is especially aimed at reducing injuries to the back and spine.

TABLE 5.5 MEASURES TO IMPROVE REAR IMPACT CRASH OCCUPANT PROTECTION

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	%	MAIS 3+ (N = 188) N	%
Risk factor: Rear impact (rear of vehicle struck)									
7	Improved rear impact crashworthiness: Rear impact crash test (MAIS 3+ injury applicable)[111,112]	V	V-1	Medium	Now	10	2.5%	10	5.3%
7	Optimised anti-whiplash seat (includes all severity neck and spine injuries for rear impact cases)[113,114,115]	V	V-1	Medium	Now	18	4.5%	9	4.8%

111 Per US FMVSS 301, Rear Impact test, for example. Parenteau C, Stephens G, Yaek J, Gregory S. The effect of FMVSS 301R on vehicle structure in rear impact. SAE Technical Paper 2020-01-1226, 2020.

112 Viano DC, Parenteau CS. Effectiveness of the revision to FMVSS 301: FARS and NASS-CDS analysis of fatalities and severe injuries in rear impacts. Accident Analysis and Prevention. 2016;89:1-8.

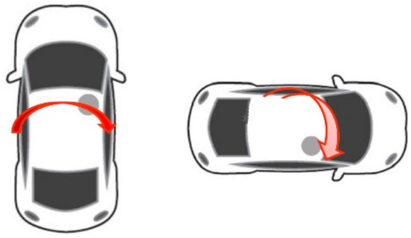
113 Himmetoglu S, Acar M, Bouazza-Marouf K, Taylor AJ. Car seat design to improve rear-impact protection. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. 2011;225(4):441-459.

114 Krafft M, Kullgren A, Ydenius A, Boström O, Håland Y, Tingvall C (2004) Rear impact neck protection by reducing occupant forward acceleration – A study of cars on Swedish roads equipped with crash recorders and a new anti-whiplash device. Proceedings of the IRCOBI Conference on the Biomechanics of Impacts; 22 - 24 September 2004, Graz, Austria; 2004.

115 Svensson MY, Boström O, Davidsson J, Hansson HA, Håland Y, Lövsund P, Suneson A, Säljö A. Neck injuries in car collisions - a review covering a possible injury mechanism and the development of a new rear-impact dummy. Accident Analysis and Prevention. 2000 Mar;32(2):167-75.

5.1.3.4 Addressing injury in rollover events

With 16.8% (n = 67 of 400) of ECIS case drivers experiencing a rollover event, this impact is common. Rollover events are also highly injurious, with 41.8% (n = 28 of 67) involved drivers sustaining MAIS 3+ injuries; this translates to 14.9% of all drivers sustaining MAIS 3+ injuries. Rollover events were seen in Lane Departure and Across Path crashes (see *ECIS Report 3*).



Rollover impact

Countermeasures aimed at addressing injuries sustained in rollover events include:

- Implementation of a rollover protection test, as performed in overseas jurisdictions.[116] This is applicable to all drivers injured in rollover events.
- Per above, but with a focus on the prevention / mitigation of MAIS 3+ injuries, particularly those of the head, face, neck, and the spinal cord; 29.9% (n = 20 of 67) of drivers experienced these injuries at the MAIS 3+ severity level, translating to 5.0% of all injured drivers (20 of 400).
- Rollover injury mitigation measures, including optimised seat belt systems, roof padding and a centre (roof-based) airbag; the latter being especially relevant where passengers are present (23.9%, n = 16 of 67).

TABLE 5.6 MEASURES TO IMPROVE ROLLOVER CRASH OCCUPANT PROTECTION

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Rollover event, with at least 1/4 turn									
7	Rollover protection test (implementation)	V	V-1	High	Now	67	16.8%	28	14.9%
7	Rollover protection test, to mitigate MAIS 3+ head, face, neck, cervical / thoracic spine injuries / lumbar injuries	V	V-1	High	Now	20	5.0%	20	10.6%
7	Rollover injury mitigation countermeasures (i.e., seat restraint, roof padding / roof airbag / centre-line airbag)	V	V-1	High	Now	67	16.8%	28	14.9%
7	Centre-line airbag, to mitigate occupant interaction where front-left passengers present	V	V-1	High	Now	16	4.0%	3	1.6%

116 Brumbelow ML, Teoh ER. Roof Strength and Injury Risk in Rollover Crashes of Passenger Cars. Traffic Injury Prevention. 2009;10(6):584-92.

5.1.3.5 Addressing other impact-related injury risk factors

A range of other injury risk factors were observed. Measures to address these injury factors are presented in Table 5.7 (also see *ECIS Report 3* for complete data).

An impact with an 'incompatible' vehicle (based on mass and geometry) occurred for 12.5% of injured drivers; 62.0% sustained MAIS 3+ injuries (n = 31 of 50; 16.5% of drivers with MAIS 3+ injuries, n = 31 of 188). Countermeasures include the fitment of active safety systems for commercial vehicles in line with those outlined for passenger vehicles, with consideration given to vehicle access, lane use and travel speed requirements for commercial vehicles.

Measures to address injury associated with secondary impacts are required. Identified measures include automatic braking and secondary occupant protection measures, such as dual inflation airbags. These scenarios are complex to manage but occurred for 21% of drivers.

The fitment of impact underrun protection, whilst influencing a small proportion of injured drivers, is highly efficacious, as are measures to prevent occupant ejection and vehicle fires. The use of energy-absorbing bull-bar systems to replace a rigid system is necessary for the protection of 11.8% of involved drivers (n = 47 of 400; MAIS 3+: 14.9%, 28 of 188; Note: both A and B vehicles in a single crash had a rigid bull bar fitted).

TABLE 5.7 MEASURES TO ADDRESS INJURY ASSOCIATED WITH OTHER VEHICLE-RELATED FACTORS

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Impact with 'incompatible' vehicle based on mass/geometry differential (Note: limited to truck, bus, commercial van /utility)									
7	Further enhancements in occupant protection (active systems) and lane use / speed limited requirements of commercial vehicles	V	V-1	Up to Medium	Now	50	12.5%	31	16.5%
Risk factor: Underrun for ECIS Case vehicle, associated with frontal impact direction									
7	Fit rear-impact or side underrun to B-vehicle (heavy vehicle)	V	V-1	High	Now	5	1.3%	3	1.6%
Risk factor: Impact in (A) or against (B) vehicle with rigid bull (or nudge) bar, in frontal impact crashes									
7	Fit non-rigid / energy absorbing bull-bar [A-vehicle]	V	V-1	Medium	Now	30	7.5%	16	8.5%
7	Fit non-rigid / energy absorbing bull-bar [B-vehicle]	V	V-1	Medium	Now	18	4.5%	14	7.4%
Risk factor: Occupant ejected (complete) from vehicle									
7	Improved door strength	V	V-1	High	Now	5	1.3%	3	1.6%
7	Seat belt use (and associated optimised seat belt systems)	V	V-1	High	Now	4	1.0%	2	1.1%
7	Window (glass) strength	V	V-1	Medium	Now	2	0.5%	2	1.1%
Risk factor: Vehicle fire									
7	Fuel line / tank integrity	V	V-1	High	Now	3	0.8%	2	1.1%
Risk factor: Multiple impacts experienced by vehicle									
7	Secondary / multi-collision brake & occupant protection supplementary restraint (airbag, seat belt) measures	V	V-1	Medium	Now	84	21.0%	40	21.3%

5.1.4 Measures to address impact speed: reducing impact speed within the safety envelope of the vehicle

The success, or otherwise, in the management of crash energy is a critical determinant of the type and severity of injuries sustained by drivers and other vehicle occupants. The occupant protection measures described above with respect to the ECIS driver sample are focussed on mitigating injury severity once a crash occurs.

As described in detail through the ECIS Report series, impact speed is the principal determinant of the level of energy in the crash. Vehicle mass and the rigidity of the opposing vehicle / object influence the magnitude of energy the driver is exposed to. The moderation of impact speed is therefore a key objective. Ensuring that the vehicle speed at impact, and hence impact speed, is at a value that the vehicle can 'manage' (i.e., within the impact speed safety envelope) is central to reducing serious injury crashes.

The importance of managing speed is emphasised by the reference to speed as being the 'regulator' of the safety of the road transport system in the *Vision Zero* framework. These concepts are discussed in detail in *ECIS Report 1*, with robust evidence supporting these concepts provided in *ECIS Reports 1, 2 and 3*. *ECIS Report 2* demonstrates a clear relationship between the speed limit, driver speed choice, travel speed and hence impact speed, and injury severity.

Analysis of the ECIS data shows that for 67.3% of ECIS case drivers (n = 269 of 400), the crash occurred at a speed higher than the threshold at which the vehicle could be expected to protect the driver from serious injury (see Appendix D).[117]

This was especially evident amongst drivers involved in Lane Departure crashes (MAIS 1+: 77.7%, n = 157 of 202; MAIS 3+: 82.8%, n = 96 of 116) (see *ECIS Report 3* for detail). The direct link to serious injury is further reinforced by the finding that 80.3% (n = 151 of 188) of drivers sustaining a MAIS 3+ injury experienced a crash with an impact speed beyond the safety envelope given the vehicle star-rating, collision partner/object, and impact direction.[117] Addressing impact speed is therefore critical. Countermeasures focussed on managing impact speed are presented in Table 5.8.

Identified countermeasures to reduce impact speed to be within the safety envelope of the vehicle are:

- Reduction in the speed limit.
    - Applicable to all crashes where the impact speed boundary condition is exceeded. This translates to 67.3% (n = 269 of 400) of injured drivers, and 80.3% of drivers sustaining MAIS 3+ injuries (see Appendix E for disaggregation by speed zone and urban/rural crash locations). Further evidence of the need for this countermeasure is demonstrated by the finding that the impact speed was above the safety threshold for 41.1% of drivers of 5-star rated vehicles (n = 37 of 90).
    - This countermeasure has high applicability, high efficacy and is system wide in its effect when applied. This benefit is based upon aligning speed limits with Safe System compliant levels which are informed by the relationship between speed limit, choice of travel speed, impact speed and injury severity (see Appendix D for boundary condition impact speeds given the safety rating of the vehicle, impact type and collision partner; refer to *ECIS Report 2*).
- Via the activation of AEB prior to the crash.
    - This is applicable to 43.0% of crashes (n = 172 of 400), or to 63.9% of drivers (n = 172 of 269) where the impact speed safety envelope was exceeded. This represents a subset of injured drivers as the crash must also satisfy the performance requirements of AEB (see Section 4.1.12; Table 4.16).
    - AEB effectiveness is dependent upon the time-to-collision being sufficiently long enough to achieve an effective reduction in speed. For context, the crash reconstruction analysis performed in ECIS showed that 55.0% of crash-involved drivers braked pre-crash, and when they did, it was only for 1.3 seconds on average. For the remaining 45.0% of crash involved drivers, no braking was attempted. These data indicate that the time-to-collision was very short. Notwithstanding this, it is highly probable that AEB can play a role in reducing impact speed, and hence injury severity, in many of these crashes.

117 The safety envelope, or boundary condition, impact speed is a function of the star-rating of the driver's vehicle, the impact direction, and the collision/impact object; impact speed was determined in the ECIS program using full crash reconstruction. See ECIS Report 1 and ECIS Report 2 for detail.

- Achieve full fleet penetration of 5-star rated vehicles, either through natural attrition and/or a vehicle replacement scheme (without changing speed limits).
    - Assuming all ECIS case drivers of 4-star and lower safety rated vehicles (MAIS 1+: n = 310; MAIS 3+: n = 158) were in a 5-star safety rated vehicle at the time of the crash, an additional 22.0% of all MAIS 1+ ECIS driver crashes (n = 400) and an additional 23.4% of all MAIS 3+ ECIS driver crashes (n = 188) would **occur within** the in-built safety envelope of the vehicle (see Appendix F).
        - This was derived by using the impact speed of the ECIS crash (i.e., impact speed remains constant) but with the higher impact speed safety envelope threshold of 5-star safety rated vehicles being used. This is akin to substituting the ECIS case driver's vehicle at the time of the crash with a vehicle that provides 5-star occupant protection level of safety.
    - With all 400 ECIS case drivers in a 5-star safety rated vehicle at the time of the crash, the impact speed for 45.3% (n = 181 of 400) of drivers would continue to be above the in-built safety envelope of the vehicle (MAIS 3+: 56.9%, n = 107 of 188). Hence, irrespective of the mechanism by which all vehicles in the fleet hold a 5-star safety rating (e.g., through natural attrition, vehicle replacement scheme), nearly half of all crash-involved drivers would continue to experience impact speeds beyond the ability of their vehicle to protect them from serious injury (see Appendix F). This data reinforces the need for the implementation of system-wide measures to address this risk factor.
- Infrastructure measures that influence the crash in such a way that the energy of the crash is reduced by design. These measures, which can be implemented system-wide, are outlined in the following sections specific to Lane Departure crashes, Across Path crashes and Rear Impact crashes.

TABLE 5.8 MEASURES TO ADDRESS IMPACT SPEED

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Impact speed outside vehicle safety envelope, based on primary impact point and NCAP star-rating									
7	Reduce impact speed via reduction in the speed limit (see Appendix E)	R, S	R	High	Now	269	67.3%	151	80.3%
7	Reduce impact speed via Autonomous Emergency Braking (AEB)	V, S	V-2	Medium - High	Now	172	43.0%	97	51.6%
7	Replace 4-star or lower safety ANCAP rated vehicles with 5-star safety rated vehicles (natural attrition, vehicle replacement scheme) [assumes no change in speed limits] (see Appendix F)	V	V-1	High	Now[118]	88	22.0%	44	23.4%
7	Infrastructure measures to address impact direction (angle) (see infrastructure measures; e.g., install roundabout, realign intersection)	R	R	Medium - High	Now	269	67.3%	151	80.3%
7	Infrastructure measures to prevent collision event and dissipation of crash energy (see infrastructure measure; e.g., install appropriate barrier, install frangible pole)	R	R	Medium - High	Now	269	67.3%	151	80.3%

118 Natural turnover is occurring now, however full fleet penetration will occur beyond the medium-term. This reflects the age distribution of the passenger car fleet, current vehicle turnover, and attrition of the fleet. From the time a new vehicle technology is introduced and fitted to all new vehicles sold, full fleet penetration can take 29 years; see: Fitzharris and Stephan (2013). Assessment of the need for, and the likely benefits of, enhanced side impact protection in the form of a Pole Side Impact Global Technical Regulation (see: https://wiki.unece.org/download/attachments/15237355/PSI-RD-06.pdf?api=v2).

5.2 MEASURES TO ADDRESS INJURY RISK FACTORS SPECIFIC TO LANE DEPARTURE CRASHES

5.2.1 Infrastructure measures to manage injury associated with departing the lane

Infrastructure countermeasures play a central role in preventing vehicles from striking another vehicle or leaving the road entirely. These same measures also play a crucial role in managing the energy of a crash, thereby acting to mitigate the severity of injuries sustained.

As described earlier and in *ECIS Report 3*, vehicles moving beyond their travel lane represent the primary risk factor for the crash. Countermeasures to address these vehicle movements are presented in Table 5.9. Percent values are expressed as a function of the number of drivers injured in Lane Departure crashes (i.e., MAIS 1+: n = 202; MAIS 3+: n = 116), as well as a function of the total ECIS driver sample (i.e., MAIS 1+: n = 400; MAIS 3+: n = 188).

Installation of centreline or roadside barriers represent the primary infrastructure measure at this point of the crash sequence. Installation of energy-absorbing barrier systems was identified as being required and being feasible at the crash site of 69.8% of drivers injured in Lane Departure crashes (n = 141 of 202; MAIS 3+ 75.0%, n = 87 of 141). This high efficacy countermeasure is relevant to 35.5% of the ECIS driver sample (n = 141 of 400) and provides coverage for 46.3% drivers who sustained MAIS 3+ injuries (n = 87 of 188).

TABLE 5.9 MEASURES TO ADDRESS VEHICLE MOVEMENTS IN LANE DEPARTURE CRASHES

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (n = 202) (N = 400)		MAIS 3+ (n = 116) [N = 188]	
						N	%	N	%
Risk factor: Deviated from lane									
7	Install barrier to address crash event movement and crash energy inclusive of perceptual measures† # ‡ (qualifier: feasible)	R	R	High	Now	141	69.8% [35.3%]	87	75.0% [46.3%]
7	Speed limit reduction required if elect not to install barrier (subset of above; given current speed limit >= 80 km/h)	R, S	R	High	Now	102	50.5% [25.5%]	58	50.0% [30.9%]
7	Speed limit reduction required as required barrier installation not feasible	R, S	R	High	Now	25	12.4% [6.3%]	14	12.1% [7.4%]
Risk factor: Vehicle crossed centre line resulting in head-on crash or struck object following loss of control									
7	Install centre barrier (with 2+1 assessment); inclusive of perceptual measures† #	R	R	High	Now	95	47.0% [23.8%]	59	50.9% [31.4%]
Risk factor: Vehicle crossed centre line and departed road to right (striking object following loss of control)									
7	Install right barrier inclusive of perceptual measures† # (with 2+1 assessment)	R	R	High	Now	30	14.9% [7.5%]	21	18.1% [11.2%]
Lane departure: Vehicle departed road to left (striking object following loss of control)									
7	Install left barrier inclusive of perceptual measures† # (with 2+1 assessment)	R	R	High	Now	73	36.1% [18.3%]	43	37.1% [22.9%]

† Barrier types include wire rope barriers and flexible/non-flexible w-beam systems, the latter applied in lower speed zones where vehicles departed the road and struck an object, or to protect against drains, culverts, embankments where flexible wire rope barrier not feasible due to dynamic flexion. # Inclusive of audio-tactile lane delineation measures (ATLM), lane delineation (painted centre/edge line) and raised reflective pavement markers (RRPMs) or other fluorescent measure for visual guidance (combination).

‡ Applicable crashes (n = 141) occurred in rural (60.3%, n = 85) and metropolitan areas of Victoria (39.7%, n = 56); on all road types (M: 7.1%, n = 10; A: 7.1%, n = 10; B: 8.5%, n = 12; C: 34.8%, n = 49; Arterial: 11.3%, n = 16; Local: 31.2%, n = 44); and across all speed zones (110 km/h: 2.8%, n = 4; 100 km/h: 51.1%, n = 72; 90 km/h: 2.8%, n = 4; 80 km/h: 17.7%, n = 25; 70 km/h: 9.9%, n = 14; 60 km/h: 13.5%, n = 19; 50 km/h: 2.1%, n = 3).

Following on from the above, should a decision be taken that the required crash protection barrier not be installed, the speed limit would need to be reduced. This is required to manage the impact speed to a level at which a 5-star vehicle could provide protection against serious injury. This measure was applicable to crash locations with a speed limit of 80 km/h or higher. This measure was applicable to 50.5% of crash sites where a driver was injured (n = 102 of 202). Another way to express this is that speed limit reductions are required at 72.3% (n = 102 of 141) of crash sites if the required flexible barrier system is not installed.

Furthermore, barrier installation was assessed as not feasible at 60 crash sites (29.7%, of 202).[119] To ensure adequate protection for these drivers, speed limit reductions are required at sites that had a speed limit of 80 km/h or higher (n = 25; 12.4% of 202). Speed limit reductions are therefore required at 41.6% (n = 25 of 60) of crash locations where installation of a barrier is required but is not feasible due to site specific factors, such as lane width and surrounding land use/topography; all but three of these locations were in rural Victoria (88.0%) and 19 of the 25 crashes (76.0%) occurred on C-class (n = 4) or Local roads (n = 19). This measure is in view of the need to manage the energy of the crash by reducing impact speed (see Section 5.1.4 for an explanation of this rationale).

Table 5.9 also provides data relevant to the installation of centreline barriers, as well as barriers to the right side of the vehicle in relation to its direction of travel and barriers to manage vehicles departing the road to the left. Due to the nature of pre-crash movements, vehicles can move in multiple directions, necessitating installation of multiple barriers. Taking a Safe System perspective, installation of centreline and barriers at the roadside are required on roads with a speed limit greater than 70 km/h (see *ECIS Report 1*, Chapter 8).

TABLE 5.10 MEASURES TO ADDRESS VEHICLE IMPACTS IN LANE DEPARTURE CRASHES

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (n = 202) [N = 400] N	%	MAIS 3+ (n = 116) [N = 188] N	%
Risk factor: Presence of, and impact with rigid pole									
7	Replace pole to address rigidity and/or placement to roadside	R	R	Medium	Now	19	9.4% [4.8%]	8	6.9% [4.3%]
7	Apply energy (crash) absorption material, and/or install appropriate barrier guard	R	R	High	Now	19	9.4% [4.8%]	8	6.9% [4.3%]
Risk factor: Presence of, and impact with unprotected tree									
7	Remove, move, or replant vegetation with different plant	R	R	Medium	Now	87	43.1% [21.8%]	49	42.2% [26.0%]
7	Apply energy (crash) absorption material, and/or install appropriate barrier guard	R	R	High	Now	87	43.1% [21.8%]	49	42.2% [26.0%]
Risk factor: Impact with embankment, inclusive of unprotected drain/culvert associated with poor shoulder edge									
7	Realign embankment and correct compromised shoulder and drainage (ditch, drain, culvert) to prevent vehicle rollover	R	R	Medium	Now	19	9.4% [4.8%]	7	6.0% [3.7%]

5.2.2 Infrastructure measures to manage injury associated with impacts with roadside objects

Half (52.5%) of drivers injured in a Lane Departure crash struck a tree (43.1%) or rigid pole (9.4%). Measures to address these are the installation of an appropriate barrier guard and/or the application of energy absorbing material, revegetation of the area and tree removal, and the use of frangible poles in place of rigid poles.

In addition, 9.4% of drivers were injured following an impact with an embankment. Remediation works include realignment, correction and extension of the shoulder and coverage of drains to prevent vehicle rollover.

119 Of the 60 sites, 35 (58.3%) had a speed limit of 70 km/h or lower, 32 were in metropolitan Victoria, 3 were in rural Victoria; all but 3 sites had a speed limit of 60 km/h or lower. Of the 25 sites where a speed limit reduction is required 22 were in rural Victoria and 3 were in metropolitan Victoria; crash by road class as follows, A: 1; B: 3; C: 4; Arterial: 1; Local 15.

5.3 MEASURES TO ADDRESS INJURY RISK FACTORS SPECIFIC TO ACROSS PATH CRASHES

Vehicle movements at intersections are complex, with drivers exposed to highly injurious side impact crashes and frontal impact crashes. These movements are defined by the layout of the intersection itself which dictates vehicle conflict points. As outlined throughout this *Report*, vehicle and road infrastructure measures can act to positively influence driver decision-making. The findings of the ECIS program demonstrate the negative influence of the totality of intersection design in shaping driver error (see *ECIS Report 1*, Section 6.4.2).

Intersection design and the speed limit settings can play a critical role in driving injury severity by dictating the nature of conflict between vehicles. The corollary is safety by design that can fundamentally alter the nature of vehicle interactions and the level of injury in the event of a crash. To this end, countermeasures to address three Across Path crash scenarios identified below are presented in the following section. The three Across Path crash scenarios are as follows:

1. Vehicle enters carriageway, or turns across another vehicle, resulting in crash occurring at incompatible angle and high impact speed.[120]
2. Turning off carriageway on high-speed road (80 km/h +).[121]
3. Cross traffic/turn includes scenarios where vehicles were travelling perpendicular to one another through an intersection.[122]

Close to one-third of the ECIS driver sample were injured in Across Path crashes (30%, n = 120 of 400); of these 44.2% (n = 53 of 120) sustained MAIS 3+ injuries. Further detail is provided in *ECIS Report 3*.

Table 5.11 identifies countermeasures assessed to be applicable to reducing the injury severity of the crash and the injured driver. Each measure is regarded to have high efficacy and is available for implementation now.

Relevant measures for these vehicle movements in this part of the crash sequence are:

- Reductions in the speed limit, with a view of reducing the risk of a crash and reducing the impact speed if a crash occurs. Supporting measures include Side Road Activated Speed (SRAS) systems.
- Closure of centre islands to prevent turn across vehicle movements.
- Installation of dedicated turning lanes.
- Structural redesign of intersections to eliminate conflict points.
- Installation of roundabouts, with a view to speed management, reducing impact speed at impact, and optimising traffic flow to minimise congestion. Sites where the installation of traffic lights was a feasible option were also identified; this was based on these locations having a high traffic volume that would necessitate two (or more) lanes within the roundabout.
- Grade separation of key arterial routes and of train lines, to eliminate conflict points entirely.

Acknowledging that the driver has moved into the crash phase, the intention of these countermeasures is to manage the nature of the conflict and the level of energy that occurs once the travel path of vehicles intersect. This is the very nature of Across Path crashes. For this reason, these measures do not supersede or replace infrastructure measures applicable to earlier phases in the crash sequence that aim to return the driver to a state of *Normal Driving*.

120 MAIS 1+: 33.3%, n = 40 of 120; MAIS 3+: 34.0%, n = 18 of 53.
121 MAIS 1+: 3.3%, n = 4 of 120; MAIS 3+: 1.9%, n = 1 of 53.
122 MAIS 1+: 72.5%, n = 87 of 120; MAIS 3+: 75.5%, n = 40 of 53.

TABLE 5.11 MEASURES TO ADDRESS VEHICLE MOVEMENTS IN ACROSS PATH CRASHES

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 120) [N = 400] N	MAIS 1+ %	MAIS 3+ (N = 53) [N = 188] N	MAIS 3+ %
Risk factor: Vehicle enters carriageway, or turns across vehicle, resulting in crash occurring at incompatible angle and high impact speed									
7	Reduce (modify) speed limit in proximity to intersection (80 km/h or higher speed limit roads)[123]	R, S	R	High	Now	32	26.7% [8.0%]	18	33.9% [9.6%]
7	Side Road Activated Speed (SRAS) systems[124, 125] (enter-carriageway) (no traffic lights present) (Type F, H)	R, S	R	High	Now	20	16.7% [5.0%]	13	24.5% [6.9%]
7	Prevent turn across by closing middle island (centre median) and associated right turn (Type F, G)	R	R	High	Now	17	14.2% [4.3%]	5	9.4% [2.7%]
7	Install / require Michigan Left turn address turn across (Type F)[126]	R	R	High	Now	17	14.2% [4.3%]	6	11.3% [3.2%]
Risk factor: Turning off carriageway on high-speed road									
7	Reduce the speed limit on roads with a speed limit >= 80 km/h	R, S	R	High	Now	4	3.3% [1.0%]	1	1.9% [0.5%]
Risk factor: Cross traffic/turn									
7	Close right turn at traffic lights - intersection redesign / cut-through (traffic lights present)	R	R	High	Now	3	2.5% [0.8%]	2	3.8% [1.1%]
7	Realign intersection by physically relocating lanes/change intersection geometry / intersection point	R	R	High	Now	18	15.0% [4.5%]	8	15.1% [4.3%]
7	Close intersection completely (Type F, G)	R	R	High	Now	5	4.2% (1.3%]	2	3.8% [1.1%]
7	Install roundabout (qualifier: feasible) [intent: prevent conflict, change impact angle][127]	R	R	High	Now	76	63.3% [19.0%]	34	64.2% [18.1%]
7	Install roundabout with traffic signals (volume, road function) - prevent conflict, change angle impact, force decision making / control flow	R	R	High	Now	39	32.5% [9.8%]	11	20.8% [5.9%]
7	Diamond interchange to prevent right turn across	R	R	High	Now	4	3.3% (1.0%]	2	3.8% [1.1%]
7	Grade separation possible (eliminate conflict)	R	R	High	Now	10	8.3% [2.5%]	5	9.4% [2.7%]
7	Grade separation at rail level crossing possible (eliminate conflict)	R	R	High	Now	1	0.8% [0.3%]	1	1.9% [0.5%]

123 Qualifier: based on impact speed exceeding the envelope and/or MAIS 3+ injury sustained by driver.
124 See for example: Side Road Activated Speeds, https://ca-v2.s3-ap-southeast-2.amazonaws.com/vicroads/safer-roads/doc-srars.pdf; also: Peiris S, Corben B, Nieuwesteeg M, Gabler HC, Morris A, Bowman D, Lenné MG, Fitzharris, M. Evaluation of alternative intersection treatments at rural crossroads using simulation software. Traffic Injury Prevention. 2018;19(S2):S1-S7.
125 Morris S. Side Road Activated Speeds (SRAS) and Treatment of high-risk rural intersections. https://www.ite.org.au/wp-content/uploads/2019/03/2.-Sarah-Morris-ITEANZ-SRAS-presentation-Feb-19.pdf
126 'Michigan Left', as applied in Australia requires a driver who intends to proceed right first must turn left to enter a carriageway, executes a U-turn at a dedicated median opening and merges and proceeds in the direction as planned. This allows for closure of a wide centre median opening and prevents drivers performing a right turn across traffic lanes; implemented to prevent side impact crashes.
127 Intersection of: Local (municipal) road with A, B, or C road: n = 19, 25.0%; Local with Local or Arterial: n = 34, 44.7%; Arterial with Arterial: n = 9, 11.8%; Arterial with M: n = 5, 6.6%; Arterial with C: n = 3, 3.9%; A with C: n = 2, 2.6%; B with C: n = 3, 3.9%; C with C: n = 1, 1.3%.

5.4 MEASURES TO ADDRESS INJURY RISK FACTORS SPECIFIC TO REAR IMPACT CRASHES

A small proportion of Rear Impact crashes occurred following a deviation from the travel lane or occurred in the confines of an intersection.

Relevant countermeasures aimed at addressing factors associated with crash and injury risk relevant to the crash phase of Rear Impact crashes are presented in Table 5.12. While influencing a small proportion of the total crash burden, the installation of these measures is feasible with all but one being rated as having high efficacy. These measures play an important role in protecting the driver during the crash phase, and in doing so provide an additional line of defence in the protection of the driver from injury. As such, these countermeasures serve to complement countermeasures implemented earlier in the crash sequence.

TABLE 5.12 MEASURES TO ADDRESS VEHICLE MOVEMENTS IN REAR IMPACT CRASHES

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 69) [N = 400] N	%	MAIS 3+ (N = 14) [N = 188] N	%
Risk factor: Intersection: Turning off carriageway on high-speed road									
7	Reduce the speed limit on roads with a speed limit >= 80 km/h	R, S	R	High	Now	4	5.8% [1.0%]	3	21.4% [1.6%]
Risk factor: Intersection: Cross traffic/turn									
7	Close right turn at traffic lights - intersection redesign / cut-through (traffic lights present)	R	R	High	Now	1	1.4% [0.2%]	0	0.0% [0.0%]
7	Install roundabout (qualifier: feasible) [intent: prevent conflict, change impact angle, reduce speed][128]	R, S	R	High	Now	4	5.8% [1.0%]	1	7.1% [0.5%]
7	Install roundabout with traffic signals (volume, road function) - prevent conflict, change angle impact, force decision making / control flow	R, S	R	High	Now	2	2.9% [0.5%]	1	7.1% [0.5%]
7	Grade separation possible (eliminate conflict)	R	R	High	Now	4	5.8% [1.0%]	1	7.1% [0.5%]
Risk factor: Deviated from lane - vehicle crossed centre line									
Installation of barrier not applicable to crash event (n = 1, 0.2% of 400; MAIS 3+ injury severity)									
Risk factor: Presence of, and impact with rigid pole, secondary to Rear Impact collision									
7	Replace pole to address rigidity / frangibility and/or placement on roadside	R	R	Medium	Now	2	2.9% [0.5%]	0	0.0% [0.0%]
7	Install appropriate barrier guard	R	R	High	Now	2	2.9% [0.5%]	0	0.0% [0.0%]

128 Intersection of Arterial with Arterial: n = 4.

6 MEASURES TO SUPPORT EMERGENCY RESPONSE AND ACUTE TRAUMA CARE

Immediately following the crash there is a need to provide emergency care for the injured driver. The processes that underpin the provision of this care are the focus of Phase 8 of the ECIS ISC.

The notification of the crash to ambulance services initiates a series of actions using established protocols that aim to provide acute emergency care and transportation of the injured driver to a trauma hospital for definitive care in the shortest time possible. These steps include the allocation of resources to the crash including other supporting emergency services, the provision of acute care at the scene, extrication of the injured driver from the damaged vehicle, and transport to a trauma hospital for definitive care. These time critical steps are the first stage of the road to recovery for injured drivers. The extent to which these services are resourced and integrated with one another plays a key role in not only determining the immediate survival of injured drivers following a crash, but also shapes their recovery and return to their pre-crash way of life.

All drivers enrolled to the ECIS program, due to the way the study was designed, required assessment and acute medical care for the treatment of injuries sustained in the crash. While the ECIS program adopted a formal definition of serious injury of MAIS 3+ (47.0%, n = 188 of 400), 79.0% (n = 316 of 400) sustained a MAIS 2 or higher severity injury, with 36.5% (n = 146 of 400) meeting the injury criteria of major trauma. These data demonstrate the high acuity nature of the injuries sustained by the ECIS driver cohort and their need for urgent care. Demographic and other factors, as well as mechanistic criteria (i.e., extent of vehicle damage), also play a role in how the injured driver is managed.

This section is focussed on provision of emergency care in the immediate aftermath of the crash. Through case-by-case analysis, factors that delayed or complicated the provision of this care were identified. Measures to address these factors are outlined below (Table 6.1).

6.1 PROVISION OF EMERGENCY CARE, RESOURCING AND REMOTE LOCATIONS

All drivers required and received emergency care provided by Ambulance Victoria. Other emergency services such as the State Emergency Service (SES) and Victoria Police attended crash scenes and played important roles in scene management, extrication of injured drivers from vehicles, among other activities. These services require substantial on-going resourcing in terms of personnel, training, and equipment, with supporting quality assurance and data systems.

To facilitate rapid attendance, vehicle-based Accident Emergency Call System (AECS; commonly known in Australia as eCALL) technology represents a key safety measure. This would have been especially relevant for 42.0% of injured drivers whose crashes occurred in rural settings where passing traffic volume was low.

The crash location for a small proportion of drivers (1.3%, n = 5 of 400) was in a remote area of Victoria, while 3.0% (n = 12 of 400) of drivers were first transported to a non-trauma centre for initial care necessitating further retrieval and transport to a trauma centre for definitive care. Further resourcing in rural Victoria is required to address these scenarios.

6.2 VEHICLE TECHNOLOGY TO REDUCE DELAYS IN CRASH NOTIFICATION

Notification of emergency services of the crash — by a crash-involved person or a bystander — was known to be delayed and/or emergency services had difficulty locating the crash scene for 5.5% (n = 22 of 400) of injured drivers; of these drivers 72.3% (n = 16 of 22) had sustained MAIS 3+ injuries. Most (91.0%, n = 20 of 22) instances where there was a known notification delay were Lane Departure crashes.

AECS systems in vehicles would overcome these delays. This would ensure that the location of the crash is known and an estimate of the severity of the crash is immediately available to emergency responders. This would assist resource allocation and ensure that optimal care is provided as quickly as possible. AECS would also benefit the small proportion of drivers who self-extricated, later requiring an ambulance. Bystander education is also important with respect to notification of emergency services in the event of a crash.

6.3 MEASURES TO ASSIST THE EXTRICATION OF INJURED DRIVERS FROM VEHICLES

For 17.5% of all drivers (n = 70 of 400), the extrication from the vehicle post-crash was exceedingly difficult due to the extent of vehicle crush, the orientation of the vehicle (i.e., rollover), and its rest position away from the road (see *ECIS Report 3* for further detail). Information and training of emergency services is important to manage these scenarios; this requires ongoing resourcing including the routine provision of damaged vehicles for training purposes. Vehicle information sheets and the ability to read vehicle QR codes in real time represent a valuable training resource, particularly in relation to managing the initial in-vehicle stabilisation of the injured driver and their subsequent extrication from highly damaged vehicles with 'live' electrical systems. This is critical to ensure the safety of ambulance and other emergency service personnel at crash scenes.

TABLE 6.1 MEASURES TO SUPPORT EMERGENCY AND ACUTE TRAUMA CARE

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Efficacy	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	MAIS 1+ %	MAIS 3+ (N = 188) N	MAIS 3+ %
Risk factor: Injured driver requiring emergency response, transport, treatment, and acute care									
8	Provision and resourcing of EMS (inclusive of HEMS) and acute care services, with Quality Assurance (QA) and supporting crash trauma data systems.† Provision and resourcing of trauma centres, inclusive of ED[a], ICU[b], and all surgical services	Post-crash	P-EA‡	High	Now	400	100%	188	100%
8	Per above, with specialist expertise, resources, and equipment to identify, manage and treat Major Trauma (ISS# > 12) patients	Post-crash	P-EA‡	High	Now	146	36.5%	146	77.7%
8	AECS[129] / eCALL: all crashes	V, Post-crash	V-2	Medium	Now	400	100%	188	100%
8	AECS[129] / eCALL (based on crash location)	V, Post-crash	V-2	High	Now	168	42.0%	101	53.7%
Risk factor: Crash in remote location, with consequent resource considerations									
8	Further resourcing of EMS for management of remote location crashes and challenging environmental conditions	Post-crash	P-EA‡	High	Now	5	1.3%	4	2.1%
Risk factor: Prolonged transport; including first attendance at non-trauma centre									
8	Further resourcing of EMS / acute Services to facilitate rapid transport to definitive care	Post-crash	P-EA‡	High	Now	12	3.0%	7	3.7%
Risk factor: Delayed notification and/or difficulty locating due to access/remote location									
8	AECS[129] / eCALL	V, Post-crash	V-2	High	Now	22	5.5%	16	8.5%
Risk factor: Self-extrication and initial non-ambulance care (Note: includes later Ambulance care and self-presentation to hospital)									
8	Education of road users (bystanders, family) to call 000 for transport of injured person to hospital	Post-crash	P-EA‡	Medium	Now	8	2.0%	0	0.0%
Risk factor: Difficult extrication of occupant from vehicle (due to impact damage, vehicle orientation and position)									
8	Further resourcing of EMS to facilitate extrication of trapped occupants, including access to ISO17840 compliant vehicle Emergency Response Guide (ERG) rescue sheets[130]	Post-crash	P-EA‡	High	Now	70	17.5%	50	26.6%
8	Further resourcing / training of EMS to provide advanced clinical care	Post-crash	P-EA‡	High	Now	70	17.5%	50	26.6%

Note: † EMS: Emergency Medical Services, HEMS: Helicopter Emergency Medical Services; ‡ P-EA: Post-crash Emergency and Acute care; #: Injury Severity Score; [a] ED: Emergency Department; [b] ICU: Intensive Care Unit.

129 As per UN Regulation No. 144, AECS Accident Emergency Call System.
130 There was no Battery Electric Vehicle (BEV), Plug-in Hybrid Electric Vehicles (PHEV) or Hybrid Electric Vehicle (HEV) involved in a ECIS crash. EMS will require knowledge of these vehicles for purposes of extrication to ensure their safety and that of the injured vehicle driver/occupants.

7 MEASURES TO SUPPORT INJURED DRIVERS THROUGH REHABILITATION, RECOVERY AND OTHER POST-CRASH MATTERS

Following the provision of emergency and acute medical care, the injured driver may return home immediately from hospital or may be admitted to a specialist acute care or rehabilitation centre. While some drivers will recover relatively quickly, others will require lifetime care. There are a range of measures needed to support injured drivers and their families through this process. This is the focus of Phase 9 of the ECIS-ISC. These measures are outlined in Table 7.1 and briefly noted below.

7.1 MEASURES FOCUSED ON POST-ACUTE CARE, REHABILITATION AND GOING HOME

A substantial proportion of ECIS case drivers were admitted to a rehabilitation centre (41.3%, n = 165 of 400) with a subset having been first admitted to another acute (specialist) care hospital (3.3%, n = 13 of 400; 7.8%, 13 of 165). Slightly more than half of injured drivers were discharged directly home from the treating hospital (58.5%, n = 234 of 400) (see *ECIS Report 3* for further detail). Admission to these services and discharge home requires significant planning, and hence resourcing, within the acute care hospital. This planning ensures optimal co-ordination with other services, both in the health sector and in the community. This step has the potential to be a high efficacy measure as its success can play a major role in the successful recovery of injured drivers.

7.2 MEASURES TO SUPPORT DRIVERS INJURED AND KILLED IN ROAD TRAUMA AND THEIR FAMILIES

Within the context of the delivery of acute care, rehabilitation and return home, the provision of support in managing the mental health and physical health impacts of the crash is essential. There are a range of measures that can be implemented to provide this support.

7.2.1 Support in event of loss of life

Two drivers (0.5%, of 400) enrolled to the ECIS program died because of their injuries; these drivers died in a hospital setting. Family support for the loss of their loved one is required. This includes mental health support as well as economic support where appropriate. Provision of this support needs to be done on a case-by-case basis with dignity and respect.

Across all ECIS crashes, 18 people died; in one crash two people died. Significant mental health and social support is required for all persons involved in these crashes.

7.2.2 Supporting mental health and recovery

All injured drivers by virtue of being in the crash and hospitalised have experienced a significant life trauma. Significant evidence exists for the impact of crashes on mental health.[131]

The follow-up and assessment of drivers (and persons involved) need to be undertaken. Early screening to identify 'at risk' drivers of poor mental health outcomes is a key measure. Assessment needs to include screening for pain, mental health conditions and/or psychological distress, self-harm and misuse of alcohol and other drugs. Where drivers are identified as being *at risk* of poorer health outcomes, targeted on-going specialist healthcare support needs to be provided.

7.2.3 Supporting physical health and recovery

Drivers enrolled to the ECIS program sustained a broad range of injuries. While serious injury was defined as MAIS 3+ severity and all drivers require care, injuries require specific and specialist forms of management.

Table 7.1 highlights drivers sustaining Traumatic Brain Injury (TBI), Spinal Cord Injury (SCI) and fractures of the limbs as injuries requiring specific care, although this list is not exclusive. These injuries were selected based on the need for on-going, potentially life-time support, particularly injuries of the head and spine. Injuries of the lower limbs can have profound and long-lasting impacts on mobility and return to everyday life.

The range of these injuries demonstrates the need for co-ordinated care, from the hospital setting through to community health services. Involvement of family and other social supports in this journey is also of value, with these persons requiring supportive education and mental health support as well.

131 For review, see: Fitzharris M. (2006). The road to recovery: Coping with the impact of traffic crashes. PhD dissertation, Monash University. Extensive other scientific papers on this subject exist.

TABLE 7.1 MEASURES TO SUPPORT THE PHYSICAL AND MENTAL HEALTH RECOVERY OF INJURED DRIVERS POST-CRASH

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Post-acute care specialist treatment and return home									
9	Rehabilitation centre admission following acute hospital, with associated re-integration home	Post-crash	P-RID	High	Now	165	41.3%	124	66.0%
9	Further admission to an acute hospital for additional treatment and/or specialist care, with associated rehabilitation and re-integration home	Post-crash	P-RID	High	Now	13	3.3%	9	4.8%
9	Home discharge planning, inclusive of out-patients, allied health and community care where required	Post-crash	P-RID	High	Now	234	58.5%	63	33.5%
Risk factor: Loss of life									
9	Provision of support (to next-of-kin, family) in relation to driver death (see below, mental health support)	Post-crash	P-RID	High	Now	1	0.3%	1	0.5%
9	Mental health support specific to involvement in fatality crash, including family support	Post-crash	P-RID	High	Now	17	4.3%	12	6.4%
Risk factor: Mental health response post-crash									
9	Early (and repeated) screening for pain, mental health conditions and/or psychological distress (inclusive of self-harm and AOD use/misuse), with appropriate segmentation and support	Post-crash	P-RID	High	Now	399	99.8%	187	99.5%
Risk factor: Injuries sustained in crash									
9	Support / programs for persons with severe and moderate TBI (based on initial GCS)	Post-crash	P-RID	High	Now	21	5.3%	17	9.0%
9	Support / programs for persons with mild TBI (based on initial GCS)	Post-crash	P-RID	High	Now	98	24.5%	60	31.9%
9	Support / programs for persons with serious (AIS 3+) injuries of the spine / spinal cord	Post-crash	P-RID	High	Now	26	6.5%	26	13.8%
9	Support / programs for persons with serious (AIS 3+) injuries of the cervical spine / spinal cord	Post-crash	P-RID	High	Now	15	3.8%	15	8.0%
9	Support / programs for persons with fractures (AIS 2+) of an upper extremity	Post-crash	P-RID	High	Now	78	19.5%	56	29.8%
9	Support / programs for persons with fractures (AIS 2+) of a lower extremity and pelvis	Post-crash	P-RID	High	Now	136	34.0%	93	49.5%

7.3 MEASURES TO SUPPORT ACCESS TO TAC (NO-FAULT) SERVICES

All drivers injured in crashes on public roads in Victoria have access to support from the *Transport Accident Commission (TAC)*. The TAC acts as a no-fault insurer and plays a key role in providing support to injured drivers.

Injured drivers, and where appropriate their family, benefit from outreach from TAC officers in the hospital setting. This early contact is important for the alignment and provision of services. Engagement with the health-care team represents an ideal model and is highly recommended.

Processes that ensure ease of access, through telephone and web-based portals, are required. The goal of these access points is to ensure that eligible drivers receive the required support as quickly as possible. On-going liaison between the injured driver, their healthcare team and the TAC is ideal.

7.4 MEASURES TO SUPPORT PROCESSES ASSOCIATED WITH INSURANCE, LICENSING AND RESUMPTION OF DRIVING

Post-crash, drivers are confronted with a range of processes relating to insurance claims, engagement with the police and with licensing authorities. Drivers benefit from these processes being clear to understand and easy to navigate.

Matters relating to the police investigation of the crash can be daunting for injured drivers and their families. Due to the severity of these crashes, these investigations can be complex and can take time. A crash may also be the subject of a coronial investigation. These investigations can have significant implications regarding licensing and other penalties. Similarly, drivers must also step through medical and/or licensing requirements to resume driving. Assistance, understanding and empathy can ease the challenging nature of these processes.

TABLE 7.2 MEASURES TO SUPPORT THE INJURED DRIVERS AND THEIR FAMILY MANAGING INSURANCE, POLICING AND LICENSING MATTERS POST-CRASH

ISC Phase	Intervention					Drivers (crashes) sensitive to intervention			
	Description of measure	SSE	Int. cat	Efficacy	Horizon	MAIS 1+ (N = 400)		MAIS 3+ (N = 188)	
						N	%	N	%
Risk factor: Access to TAC Claims									
9	TAC no-fault claims support (inclusive of medical and like support, income support, return-to-work, return-to-health, and community support for independence where appropriate)	Post-crash	P-RID	High	Now	400	100%	188	100%
Risk factor: Managing complexity of insurance matters									
9	Assistance with vehicle and other personal insurance	Post-crash	P-RID	Medium	Now	400	100%	188	100%
Risk factor: Managing complexity of police matters and resumption of driving (licensing and driving-related processes)									
9	Assistance with Police investigations and resolution of any matters relating to the crash (i.e., licensing)	Post-crash	P-RID	Medium	Now	400	100%	188	100%
9	Assistance with the management of return to driving where appropriate	Post-crash	P-RID	Medium	Now	399	99.8%	187	99.5%

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8 MEASURES TO FACILITATE CRASH DATA COLLECTION AND REPORTING

8.1 DATA SYSTEMS

The collection of sophisticated and reliable crash data is crucial to understanding the magnitude and severity of road trauma, as well as the factors associated with crash occurrence and injury severity. As demonstrated by this *Report,* understanding how crashes and injuries occur permits the identification of safety countermeasures.

The State of Victoria, where ECIS was conducted, has several highly sophisticated data systems relevant to road trauma, including:

- Ambulance data.
- Hospital administrative data, including the Victorian Emergency Minimum Dataset (VEMD) and the Victorian Admitted Emergency Dataset (VAED).
- Hospital-based Trauma Registry Data, integrated through the Victorian State Trauma Outcomes Registry and Monitoring Group (VSTORM).
- Road Crash Information System, through the Department of Transport.
- Registration and Licensing data, through the Department of Transport.
- TAC Claims file.
- Police-specific data.

These on-going data systems play a vital role in monitoring road trauma. The integration of datasets is invaluable.

The ECIS program functioned as a standalone research program where a sample of crashes was investigated at an in-depth level. In-depth studies provide high quality detailed information on the crash and can draw upon multiple information sources. The importance of these programs is recognised globally with on-going in-depth crash investigation programs being undertaken in the US (CRSS)[132], the UK (RAIDS)[133], Germany (GIDAS)[134], China (CIDAS)[135], and other countries. On-going in-depth data collection of a sample of crashes is recommended.

8.2 ON-BOARD VEHICLE CRASH DATA SYSTEMS

Modern, airbag-equipped vehicles contain an Event Data Recorder (EDR), colloquially known as the vehicle 'black box.' Information collected by the EDR, including speed, braking input, and deceleration pre-crash, is of *high value*[136] as a research tool and a crash investigation tool for police.

The EDR data was available in the vehicles of 9.8% (n = 39) of ECIS case drivers (Table 8.1). Where no EDR was available (90.3%, n = 361 of 400), either no EDR was fitted, or it was inaccessible due to the extent of vehicle damage. Further data is provided in *ECIS Report 3.*[137] Where fitted, a key barrier to the use of EDR data is lack of access.

In Australia at present, there is no uniform standard for access, use and storage of the data, nor the data variables collected and retained by the EDR technology. The adoption of UN Regulation No. 160, *Data Storage System for Automated Driving / Event Data Recorder (*DSSAD/EDR*)*[138] as an ADR is recommended. The DSSAD system is presented under development. Further legislation and administrative changes will be required to ensure access and use of the data.

The routine collection and inclusion of DSSAD/EDR data into administrative datasets will have significant advantages for crash investigation research and will facilitate the investigation work of police. This will grow

132 Crash Report Sampling System (CRSS): https://crashstats.nhtsa.dot.gov/#!/
133 Road accident in-depth studies (RAIDS): https://www.gov.uk/government/publications/road-accident-investigation-road-accident-in-depth-studies/road-accident-in-depth-studies-raids
134 German In-depth Accident Study (GIDAS): https://www.gidas.org/start-en.html
135 China In-Depth Accident Study (CIDAS). For description of CIDAS see: Chen, Q. and Dai, B., "Characteristics and Casualty Analysis of Two-Wheeler Accidents in China, Data Source: The China In-Depth Accident Study (CIDAS)," SAE Technical Paper 2018-01-1052, 2018.
136 The term 'high value' is used in place of an efficacy rating.
137 In total, an EDR was fitted to 296 vehicles (74.0%, of 400); of these, 251 (85.8%) were inspected by the ECIS Crash Investigation Team. For these 251 vehicles, the Bosch software was licenced to download of the EDR event data for 47 vehicles only (12%), of which the data was successfully downloaded for 39 vehicles. In total, download of EDR data was not supported in 241 of the 296 vehicles even where fitted (81.4%); hence, the supported rate for fitted devices was 19.6%.
138 https://unece.org/transport/documents/2021/10/standards/un-regulation-no-160-event-data-recorder-edr

increasingly important with the proliferation of automated vehicle safety systems and questions of compliance and vehicle control emerge.

TABLE 8.1 MEASURES TO FACILITATE CRASH DATA COLLECTION AND REPORTING

ISC Phase	Intervention: Description of measure	SSE	Int. cat	Value	Horizon	Drivers (crashes) sensitive to intervention: MAIS 1+ (N = 400) N	MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) N	MAIS 3+ (N = 188) %
Risk factor: DSSAD/EDR# non-uniform requirements									
10	Uniform fitment / reading requirements and access for investigation and research. Requires adoption of UN Regulation No. 160 as an ADR and associated legal changes to access, use and storage.	V	V-3	High	Now	39	9.8%	13	6.9%
Risk factor: DSSAD/EDR# unavailable / non-uniform requirements									
10	Fit EDR to vehicle	V	V-3	High	Now	361	90.3%	175	93.1%
10	Uniform fitment / reading requirements and access for investigation and research. Requires adoption of UN Regulation No. 160 as an ADR and associated legal changes to access, use and storage	V	V-3	High	Now	361	90.3%	175	93.1%

DSSAD is currently under development; UN R No. 160 currently relates to EDR technology and data.

9 PRINCIPAL FINDINGS AND CONCLUSION

This *Report,* the fourth in the ECIS Report series, presents current and future countermeasures that target specific factors identified as having contributed to the occurrence of crashes and the type and severity of injuries sustained. In doing so, this *Report* meets the second objective of the ECIS program, having examined in detail how serious injury crashes occur (see *ECIS Reports 1, 2, 3*).

The identification of factors associated with crash events and injury severity, as outlined in *ECIS Report 3,* provided the insight needed to identify measures that would address serious injury crashes. Following *ECIS Report 3,* the identification and analysis of countermeasures used a modified version of Tingvall's ISC. This permitted countermeasures to be identified for the full range of factors associated with crashes, from *Threats to Normal Driving* before the drivers' trip commenced, through each point of the crash sequence, to discharge from hospital and re-integration into the community post-crash.

Through a significant development process, an extensive library of driver, vehicle, road infrastructure, and post-crash care focused countermeasures was established. The mode of action and functional boundary was defined for each currently available and future countermeasure. Together, these represent the field-of-influence of the countermeasure. An estimate of likely efficacy in addressing the identified contributing factor in relevant crashes was also made. Countermeasure efficacy ratings were made independent of the potential influence of other crash occurrence and injury severity contributing factors that may be present in a crash.

Using a case-by-case approach, and with an understanding of all factors having contributed to the crash and to being injured, applicable countermeasures to address contributory factors in each crash were identified. Crashes and driver injuries were considered 'sensitive' to the countermeasure if they fell within the intent and functional boundary of the countermeasure specifications; if so, the countermeasure that had been linked to the contributing factor was deemed to be applicable. Multiple countermeasures were applicable to a single contributing factor in some instances.

Adopting this approach provided a comprehensive systems-based analysis of all currently available and likely future countermeasures that can play a role in reducing the incidence and severity of road trauma. Future ADAS were also included, with a time horizon estimate of their availability being made.

The primary analysis outcome of this *Report* is the proportion of hospitalised ECIS case drivers that each countermeasure will influence. An advantage of using the ISC approach is that the point of effect of each countermeasure can also be seen. This point reflects the intent and functional boundary of the countermeasure. An efficacy rating and time horizon variable provides a further basis for assessing the potential of countermeasures to reduce serious injury road trauma.

The concept of *Normal Driving* represents the starting point for understanding how to address factors associated with crash occurrence. *Normal Driving* was defined as:

1. The control of the vehicle by a driver in a manner that is responsive to the road environment, surrounding traffic and associated traffic flow, and other road users. *Normal Driving* includes being responsive to any potential threat, including that posed by another road user. *Normal driving* is therefore highly contextual.
2. Compliance with all traffic laws, inclusive of compliance with and/or responding appropriately to traffic signs/signals (i.e., traffic lights) including advisory signs.

In addition to defining *Normal Driving* in this way, basic prerequisites of *Normal Driving* were established. Any shift from this state requires intervention; this is the basis of countermeasure applicability.

Adopting this perspective recognises that the successful undertaking of a trip is influenced by factors before the trip commences. These factors are referred to as *Threats to Normal Driving* (Figure 1.1). These can be driver, vehicle or road infrastructure factors that contribute to crash risk and crash occurrence. These threats were seen to exist before the commencement of the trip, and relate to the driver, the vehicle and road and surrounding road infrastructure. Countermeasures seek to address the threat posed by these factors. The analysis presented in *ECIS Report 3* highlighted the significant need for countermeasures that address these threats, while the findings of this *Report* highlight the numerous currently available and foreseeable countermeasures to do so.

Within the trip itself, *Deviations from Normal Driving* (Phase 3) if left unchecked lead to *Emerging Situations* (Phase 4) and then *Critical Situations* (Phase 5), to a point where a crash becomes *Inevitable* (Phase 6). Countermeasures, whether they be driver-focussed, vehicle-technology, or road infrastructure-based, have the objective of encouraging, assisting, or and/or actively intervening to force the driver back to return to a position of *Normal Driving*. These measures address driver acts and decisions, whether they are done in error, were unintentional, or were deliberate acts of non-compliance. These measures, of which there is at least one matched to each contributing factor, have a crucial crash prevention role. Countermeasures also play a crucial role in mitigating the severity of injury once a crash occurs. This analysis shows that there are effective countermeasures at each point of the crash chain.

Here, the concept of safety-by-design is critical. The ability of driver, vehicle, and infrastructure countermeasures to work together to address the full range of contributing factors — and to support the driver — is integral to the safety of road users. The successful application of many of the vehicle-based technology measures will be dependent not only on the capability of sensor technology fitted on vehicles, but the capacity for vehicles to interact with one another and with the road infrastructure through V2V and V2I communication technology, respectively.

The complexity and multitude of factors that lead to drivers being in the position where a crash event is inevitable means that complete elimination of crash events is highly improbable, at least for many decades to come. This is particularly so as currently crash prevention countermeasures range in their efficacy from low-to-high, with no single countermeasure likely be 100% successful all of the time. Aligning these countermeasures to address the current crash problem is therefore imperative.

Recognising the limits of primary prevention and the need to prevent drivers (and vehicle occupants) being injured, an array of efficacious vehicle and infrastructure injury mitigation countermeasures have been developed. The need for these countermeasures is demonstrated not only by the number of road users killed in Victoria[139], but the high injury acuity of drivers involved in crashes examined in the ECIS program. Indeed, of the drivers hospitalised and enrolled to the ECIS program, approximately half sustained MAIS 3+ injuries, the average length of stay in hospital was nine days, and nearly 40% required further care and rehabilitation. In the 393 crashes examined, 18 people died in 17 crashes.

Central to the prevention of serious injury is the need to understand how injuries occur and why. This understanding leads to the development and implementation of injury control measures. Since the time of Haddon[140] – and even before – the limited tolerance of the human body to withstand the level of forces experienced in a crash is well known. Protecting drivers from injury is therefore about ensuring that the system is operated within well-defined boundaries. This requires that the vehicle and road infrastructure be designed to manage and absorb crash energy so that the driver is protected from serious injury. This is the core principle of *Vision Zero* and underpins the *Safe System* approach (see *ECIS Reports 1, 2*).

Once the crash becomes inevitable (Phase 6) and occurs, the focus shifts to the prevention of injury through the effective management and dissipation of kinetic energy (Phase 7).[141] Measures to manage the level of energy of a crash by controlling how it dissipates in the crash and how much is left for the driver's body to absorb are integral to this goal. These measures include vehicle crumple zones, energy absorbing vehicle structures and infrastructure measures such as flexible barriers.

Analysis of the ECIS data as reported in *ECIS Reports 1, 2 and 3* demonstrated that the level of energy in the road transport system as currently operated is too high, and that when crashes occur, the impact speeds seen are well beyond the ability of even the safest current vehicle to protect drivers from serious injury. Indeed, the analysis points to the primacy of managing impact speed in reducing the incidence of serious injury. This *Report* identifies high efficacy road infrastructure and vehicle-based countermeasures relevant to a high proportion of drivers that address this primary risk factor.

All injured road users require access to emergency and acute care (Phase 8), after which supportive care following discharge from hospital and services to assist the injured driver to return home and resume their pre-crash way of life complete the chain (Phase 9). A host of measures ranging from the rapid transport of injured drivers to hospital for definitive care through to managing the impacts of trauma were identified.

The range of countermeasures identified in this *Report* is extensive. This reflects the complexity of why crashes happen, and the factors associated with injury. The following section highlights selected high efficacy countermeasures and the proportion of drivers to which they relate. These data, as well as that provided in Chapters 3 to 8, can be used as the basis for taking the necessary steps to reduce road trauma in Victoria.

139 https://www.tac.vic.gov.au/road-safety/statistics/lives-lost-annual

140 Refer to ECIS Report 1 for detailed examination of Haddon.

141 In the crash phase vehicle-based and infrastructure measures are focussed exclusively on the prevention of serious injury. The design principle is that the vehicle speed and the post speed limit be in accordance with the capacity of the vehicle and the infrastructure to protect the driver (and other occupants). See ECIS Report 1 for full discussion of this point and the vehicle safety envelope concept. Kinetic Energy (KE) which is proportional to the square of the speed and the mass of the struck/striking vehicle or characteristics of the object struck (e.g., frangibility of pole/tree); the type and severity of injury is also influenced by the location of impact on the vehicle. With impact speed linked to the speed limit by shaping driver speed choice (see ECIS Report 2), this link between crash energy and injury severity is the basis for Tingvall asserting that speed acts as an overall regulator of the level of safety in the road transport system.

9.1 HIGH EFFICACY COUNTERMEASURES APPLICABLE TO SERIOUS INJURY CRASHES

The following series of Tables (9.1, 9.2, 9.3, 9.4) highlight selected high efficacy currently available countermeasures and the proportion of drivers to which they are applicable. By presenting these in the rank order of the proportion of ECIS case drivers to which they relate, an understanding of high priority driver-focussed, vehicle-focussed, road and road infrastructure-focussed countermeasures can be gained.

The objective in highlighting these countermeasures is to draw attention to those that can make a substantive difference to the level of hospitalisation severity road trauma in Victoria. This *Report* identifies multiple countermeasure opportunities across the crash sequence, each with a different focus. Implementation of a suite of carefully selected countermeasures is likely to be required given the number and extreme spread of contributing factors associated with these crashes.

In assessing countermeasure priorities, it must be recognised that while high efficacy vehicle safety countermeasures are being fitted to new vehicles, the vehicle turnover rate and rate of vehicle attrition means that it will likely take up to 29 years for all passenger vehicles to be fitted with the technology of today.[142] For this reason, every effort must be made to ensure that these technologies are regulated as standard equipment in all vehicles as expeditiously as possible. Consequently, the concurrent implementation of driver-focussed and road infrastructure countermeasures will be critical to reducing the level of serious injury that is currently seen.

Examination of the data and countermeasures in these Tables highlighted the importance of vehicle technology and infrastructure solutions in supporting and protecting drivers. The findings also highlight the primacy of speed management in the safe operation of the road transport system. These measures address not only driver travel speed but impact speed and associated crash energy that is directly associated with injury severity. Given the critical role that speed plays in dictating the overall safety of the road transport system — and the suboptimal way that each element (i.e., driver, vehicles, road infrastructure) of the current road transport system performs — these findings are unsurprising. What is clear from these data is that implementation of these measures would have a profound impact in reducing the number of drivers and other road users seriously injured in crashes.

The findings presented in Chapter 3 through Chapter 8 also highlight many currently available medium efficacy countermeasures. It is important to implement these they are applicable to a high proportion of injured drivers. This is especially the case for those that address contributing factors for which high efficacy intervening countermeasures are not currently available, for instance those that address driver drowsiness and driver distraction. Each countermeasure represents an opportunity to reduce the number of drivers (and other vehicle occupants) involved and seriously injured in a crash. Likewise, low efficacy countermeasures that are applicable to a medium-to-high proportion of crashes ought not to be ignored, particularly if they are inexpensive to implement.

Countermeasures expected to be available in the short-to-medium term were also identified. These include measures not presently implemented but where expertise exists to do so, as well as measures that will require significant technical advancement. These represent important crash prevention and injury mitigation opportunities and ought to be pursued with vigour.

For instance, future ADAS implemented through V2V and/or V2I communication technology offer significant promise in improving safety. Early and urgent regulatory efforts to ensure the continued development and rapid fitment of these technologies into future vehicles is needed, particularly in the context of the slow rate of vehicle turnover and the time taken for these technologies to penetrate the entire vehicle fleet. Likewise, there are a range of driver-focussed countermeasures that ought to be implemented.

It is also important to stress that countermeasures are required to be implemented across the crash sequence. This is because each countermeasure addresses a specific contributing factor that places stress on a different part of the crash sequence. Furthermore, no single countermeasure is 100% efficacious. Hence, every effort ought to be made to address *Threats to Normal Driving* and deviations from *Normal Driving* as they occur, thereby eliminating a potential conflict situation as early as possible. Ideally, early intervention to correct shifts in *Normal Driving* would ensure drivers would not be exposed to a crash at all. Crash events are indeed rare events; however, their consequences can be severe and life changing. It is for this reason that the road transport system must be designed and operated in such a way as to protect road users from serious injury when crashes

142 Natural turnover is occurring now, however full fleet penetration will occur beyond the medium-term. This reflects the age distribution of the passenger car fleet, current vehicle turnover, and attrition of the fleet. From the time a new vehicle technology is introduced and fitted to all new vehicles sold, full fleet penetration can take 29 years; see: Fitzharris and Stephan (2013). Assessment of the need for, and the likely benefits of, enhanced side impact protection in the form of a Pole Side Impact Global Technical Regulation (see: https://wiki.unece.org/download/attachments/15237355/PSI-RD-06.pdf?api=v2).

do occur. Specific measures that control and manage crash energy with the goal of protecting the driver are required. It is argued that to achieve an inherently safe road transport system that is truly forgiving of error, there needs to be some redundancy built into the crash chain. For this reason, the judicious selection of countermeasures across each phase in the ISC is appropriate.

There are a number of countermeasure options to address a specific contributing factor. These are clustered together. Decisions can be made on which is most suitable given other policy considerations in the planning process.

TABLE 9.1 CURRENTLY AVAILABLE DRIVER-FOCUSSED HIGH EFFICACY MEASURES (SELECT MEASURES) [ORDERED BY MAIS 1+ %]

ISC Phase†	Contributing factor to crash / injury	Countermeasure	Drivers sensitive to intervention	
			MAIS 1+ (N = 400)	MAIS 3+ (N = 188)
			%	%
3	Exceed speed limit	Speed enforcement	27.0%	36.2%
3	Exceed speed limit	Speed assistance – Intelligent Speed Assist (intervening)	27.0%	36.2%
1	Traffic offence (speed), last 12-months	Speed assistance – Intelligent Speed Assist (intervening, retrofitted)	24.8%	23.4%
1	Impairing effects of illicit drug use on driving (all substances)	Enforcement (generalised, site specific) plus community education, and associated sanctions	12.8%	17.6%
1	Impairing effects of alcohol (BAC)	Enforcement (and associated sanctions), supported with community education	11.3%	13.8%
1	Impairing effects of alcohol (BAC)	Active (manual) alcohol interlock (intervening)	11.3%	13.8%
3	Seat belt not worn	Enhanced (targeted, intense) enforcement coupled with public education (includes sanction effect component for offenders)	6.8%	7.4%
3	Failure to detect parked vehicle / objects on side of roadway	Object detection (including night vision assist & 360° surround view monitor with Head-Up Display (HUD)	4.3%	1.1%
3	Inattention in the form of using mobile phone	Enforcement - Mobile phone camera detection systems	3.8%	4.8%
1	Impairing effects of illicit drug use on driving (all substances)	Enforcement (expand roadside testing to include additional illicit substances) plus public education	1.8%	2.1%

† See Figure 1.1.

TABLE 9.2 CURRENTLY AVAILABLE VEHICLE-FOCUSSED HIGH EFFICACY MEASURES (SELECT MEASURES) [ORDERED BY MAIS 1+ %]

ISC Phase†	Contributing factor to crash / injury	Countermeasure	Drivers sensitive to intervention MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) %
7	Frontal impact crash	Measures to improve frontal impact occupant protection safety (inclusive of review of ADR69 / ADR73 for performance requirements)	68.8%	68.6%
5	Braking system suboptimal – frontal collision trajectory	Autonomous Emergency Braking (AEB) – includes all types, including Junction AEB; relies on other braking systems to be fitted (see body of *Report)*	67.0%	64.4%
5	Vehicle deviated (departed) from lane / beyond centre of lane	Automated Lane Keep Assist (ALKS): intervening for oncoming traffic crash mitigation	47.3%	53.7%
7	Impact speed exceeded safety envelope of vehicle	Reduce impact speed via Autonomous Emergency Braking (AEB) – includes all sub-types; relies on other braking systems (see body of *Report)*	43.0%	51.6%
7	Impact speed exceeded safety envelope of vehicle	Replace 4-star or lower safety ANCAP rated vehicles with 5-star safety rated vehicles [assumes no change in speed limits] #	22.0%	23.4%
7	Frontal impact crash – No frontal airbags fitted	Frontal driver airbag (advanced, dual inflation) inclusive of seat belt optimisation	17.5%	19.1%
7	Rollover, with at least 1/4 turn	Rollover protection test (implementation)	16.8%	14.9%
7	Rollover, with at least 1/4 turn	Rollover injury mitigation countermeasures (i.e., seat restraint, roof padding / roof airbag / centre-line airbag)	16.8%	14.9%
7	Frontal impact crash – Narrow frontal offset (loss of compartment integrity)	Improved frontal impact occupant protection associated structural enhancements to comply with the Narrow Frontal Offset test.	16.6%	19.7%
7	Side impact airbag sensitive crash - No head protecting airbags	Head protecting side curtain airbag (with seat belt optimisation, structural enhancements)	16.0%	21.3%
7	Side impact airbag sensitive - No thorax (including combination thorax- head) airbags	Thorax protecting side airbags (with seat belt optimisation, structural enhancements)	15.0%	20.2%
7	Side impact airbag sensitive, with front left passenger present	Centre-airbag in vehicle (front-through-rear seats)	7.0%	5.9%
7		Centre-airbag in vehicle (front-only)	6.5%	5.9%
7	Side impact airbag sensitive - impact with narrow object (tree, pole)	Measures to improve side impact protection (driven by pole side impact test, ADR 85)	5.3%	6.4%

† See Figure 1.1.

Note: EDR uniform requirements and fitment not presented in Table (see Chapter 8).

The risk factor being addressed is that the impact speed occurred above the safety envelope of the vehicle in the ECIS crash of interest. Efficacy for this measure is associated with vehicle replacement such that were the crash to happen as was in the ECIS crash, the impact speed would be within the safety envelope of the 5-star safety rated vehicle and hence the driver would be protected from serious injury. Mechanism via natural attrition or incentivised vehicle replacement scheme.

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TABLE 9.3 CURRENTLY AVAILABLE ROAD AND ROAD INFRASTRUCTURE-FOCUSSED HIGH EFFICACY MEASURES (SELECT MEASURES) [ORDERED BY MAIS 1+ %]

ISC Phase†	Contributing factor to crash / injury	Countermeasure	Drivers sensitive to intervention MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) %
7	Impact speed exceeds safety envelope of vehicle	Reduce impact speed through reduction in the speed limit#	67.3%	80.3%
	Impact speed exceeds safety envelope of vehicle	Crash location-specific infrastructure measures to prevent collision (e.g., traffic calming measures) and address dissipation of crash energy and/or impact direction (angle) (detail in *Report*, see below for high-efficacy examples) ‡	67.3%	80.3%
7	Deviated from lane	Install barrier to address crash event movement and crash energy inclusive of perceptual measures and audio-tactile measures# (qualifier: feasible)	35.3%	46.3%
	Deviated from lane	Speed limit reduction required if elect not to install barrier (subset of above; given current speed limit >= 80 km/h)	25.5%	31.4%
7	Vehicle crossed centre line, head-on crash	Install centre barrier (with 2+1 assessment); inclusive of perceptual measures#	23.8%	39.4%
1	Latent risk due to road design	Comprehensive overhaul of road infrastructure including speed limit revision	22.0%	20.7%
5	Condition of shoulder poor (associated with vehicle movement)	Seal/extend shoulder inclusive of perceptual measures # (qualifier: feasible); remove objects, rollover trip hazards, cover drains	21.8%	27.1%
7	Presence of, and impact with unprotected tree	Install appropriate crash-absorbing barrier guard	21.8%	26.0%
7	Cross traffic/turn	Install roundabout (qualifier: feasible) to prevent conflict, change impact angle, reduce impact speed; inclusive of vertical deflection	19.0%	18.1%
7	Vehicle departed road to left	Install left barrier inclusive of perceptual measures # (with 2+1 assessment)	18.3%	22.9%
7	Cross traffic/turn	Install roundabout with traffic signals (volume/ road function based); includes vertical deflection	9.8%	5.9%
1	Road alignment and/or intersection misleading	Correct alignment and/or remove relevant building/structure if feasible	8.8%	6.4%
4	Enter intersection (failed to recognise intersection)	Install traffic lights; inclusive of vertical deflection with other perceptual measures as required	7.8%	6.4%
7	Vehicle crossed centre line and departed road to right	Install right barrier inclusive of perceptual measures # (with 2+1 assessment)	7.5%	11.2%
1	Pavement surface, negative impact stability/friction	Improve road surface (i.e., grade-unsealed, improve friction, defects, drainage)	6.3%	5.3%
7	Deviated from lane	Reduction in speed limit (in lieu of barrier installation assessed as not being feasible); inclusive of perceptual measures #	6.3%	7.4%
7	Entered carriageway/ turned across (crash incompatible angle, high impact speed)	Side Road Activated Speed (SRAS) systems (enter-carriageway) (no traffic lights present) with associated perceptual measures	5.0%	6.9%

† See Figure 1.1. ‡ Percent of crash locations where one or more infrastructure countermeasure was identified. # Inclusive of audio-tactile lane delineation measures (ATLM), lane delineation (painted centre/edge line) and raised reflective pavement markers (RRPMs) or other fluorescent measure for visual guidance (combination). # Further detail of crash locations provided in Appendix E.

TABLE 9.4 CURRENTLY AVAILABLE POST-CRASH HIGH EFFICACY MEASURES CURRENTLY (SELECT MEASURES) [ORDERED BY MAIS 1+ %]

ISC Phase†	Contributing factor to crash / injury	Countermeasure	Drivers (crashes) sensitive to intervention	
			MAIS 1+ (N = 400) %	MAIS 3+ (N = 188) %
8	Injured driver required emergency response, transport, treatment, and acute care	Provision and resourcing of Emergency Medical Services (EMS) (inclusive of Helicopter-EMS) (HEMS) and acute care trauma services	100%	100%
9	Medical and other expenses incurred, including potential loss of earning	TAC no-fault claims support (inclusive of medical and like support, income support, return-to-work, return-to-health, and community support for independence where appropriate)	100%	100%
9	Involvement in hospitalisation crash (surviving driver)	Early (and repeated) screening for pain, mental health conditions and/or psychological distress (inclusive of self-harm and use/misuse of alcohol and other drugs), with on-going support	99.8%	99.5%
9	Discharged directly home from acute care hospital	Home discharge planning, inclusive of out-patients, allied health and community care where required	58.5%	33.5%
8	Injured driver required emergency response, transport, treatment, and acute care	Accident Emergency Call System (AECS) / eCALL (based on crash location)	42.0%	53.7%
9	Admission to a Rehabilitation centre following acute hospital stay	Resourcing of rehabilitation care and support for re-integration home	41.3%	66.0%
9	Driver sustained fractures (AIS 2+) of the lower extremities and pelvis	Support / programs for persons with fractures (AIS 2+) of the lower extremity and pelvis	34.0%	49.5%
9	Driver sustained mild TBI (based on initial GCS)	Support / programs for persons with mild Traumatic Brain Injury (TBI)	24.5%	31.9%
9	Driver sustained fractures (AIS 2+) of the upper extremities	Support / programs for persons with fractures (AIS 2+) of the upper extremity	19.5%	29.8%
8	Difficult extrication of occupant from vehicle (damage, vehicle orientation/position)	Further ongoing resourcing / training of EMS to provide advanced clinical care	17.5%	26.6%
8	Difficult extrication of occupant from vehicle (damage, vehicle orientation/position)	Further ongoing resourcing of EMS to facilitate extrication of trapped occupants, including access to ISO17840 compliant vehicle Emergency Response Guide (ERG) rescue sheets	17.5%	26.6%
9	Driver sustained serious (AIS 3+) injuries of the spine / spinal cord	Support / programs for persons with serious (AIS 3+) injuries of the spine / spinal cord	6.5%	13.8%
8	Delayed notification and/or difficulty locating due to access/remote location	Accident Emergency Call System (AECS) / eCALL	5.5%	8.5%
9	Driver sustained severe and moderate TBI (based on initial GCS)	Support / programs for persons with severe and moderate Traumatic Brain Injury (TBI)	5.3%	9.0%
9	Involvement in a fatality crash	Mental health support specific to involvement in fatality crash, including family support	4.3%	6.4%
9	Further admission to an acute hospital for additional treatment and/or specialist care, with associated rehabilitation and re-integration home	Resourcing of specialist acute services for management of Traumatic Brain Injury (TBI) and Spinal Cord Injury (SCI)	3.3%	4.8%
8	Prolonged transport; including first attendance at non-trauma centre	Further ongoing resourcing of EMS / acute services to facilitate rapid transport to definitive care	3.0%	3.7%

† See Figure 1.1. # Drivers injured in work-related crashes may also access support through WorkSafe, noting TAC provides coverage for all injured drivers in Victoria in the first instance. Among ECIS injured drivers, 6.2% were involved in a work-related crash.

9.2 APPLICATION OF FINDINGS, ASSUMPTIONS AND LIMITATIONS

The ECIS program was purposefully designed to be a study of passenger vehicle drivers hospitalised after involvement in a crash. It is therefore important that the findings of this *Report* are viewed and communicated with this in mind.

Specifically, the proportion of crashes to which each countermeasure is applicable to, and hence their rank order, reflects the presence of factors associated with the crash event and factors associated with injury observed in the ECIS sample. As such, the findings reflect the drivers included in the ECIS sample; consequently, the study inclusion criteria must be considered when seeking to translate these results to other contexts.

A systematic, multi-step process using multiple data points across different information sources was adopted to identify contributing factors, upon which countermeasures are based (see Report 3 for detail). This ought to give confidence in the data presented. A detailed discussion of the ECIS method and the sample is described in *ECIS Report 1*.

The data collection period for these crashes was mid-2014 to end-2016. Since this time, the global COVID-19 pandemic (from March 2020 to end 2022) caused significant supply chain disruptions that have negatively impacted on the production and delivery of new vehicles. This would likely exacerbate an already slow fleet turnover with regard to the safety of the overall fleet. Whether changes to travel patterns and vehicle use observed during the COVID-19 pandemic persist remains to be seen. Given the time passed – and with reference to future crashes – it is acknowledged that any change in driver behaviour, the safety of the fleet, and the road infrastructure that may have occurred since the time data collection ceased could impact on the rank order of countermeasures.

To the best of the authors' knowledge this *Report* identifies all available countermeasures applicable to these crashes. An assessment was made as to the efficacy of each countermeasure and its likely availability and implementation time horizon based on existing research and author expertise. It is acknowledged that the countermeasure efficacy may vary depending on the implementation context and at an individual crash level, while time horizon estimates may also change. In addition, countermeasure efficacy is based solely on the effect of the countermeasure in addressing the specified contributing factor and its influence as seen in each ECIS crash. There is no relationship between the countermeasure efficacy rating and cost-effectiveness of implementation, the latter being a policy implementation consideration.

Finally, and as reflected in *ECIS Report 3,* it is acknowledged that the sample size did not support formal statistical testing to compare the presence of a number of crash occurrence and injury severity factors and their associated countermeasures across crash types. With countermeasure identification being the primary point of interest, and the primary outcome being the proportion of serious injury crashes where a specific countermeasure was applicable, such comparisons are largely redundant. However, the reader ought to be mindful of crash/injury countermeasure sub-group analysis where percent values are high but where cell counts are small.

These aspects are important to bear in mind when seeking to apply these findings when setting future road safety priorities.

9.3 CONCLUSION

This *Report* provides a comprehensive analysis of the countermeasures currently available, and those likely to be available in the short-to-medium term. By identifying countermeasures that address specific crash occurrence and injury severity factors, then giving both their quantum and expected efficacy, it is anticipated that this *Report* represents an invaluable resource for road safety policy makers, the vehicle industry and road designers as they strive to reduce the number of people injured using the road network.

With the goal of achieving reductions in serious injury, and given the multi-factorial nature of crashes, implementation of a suite of carefully selected countermeasures across the crash sequence is likely to be required given the number and spread of contributing factors associated with these crashes. This includes measures aimed at optimising post-crash care and the recovery of injured road users. This is especially important given the significant impact on road trauma on the lives of those injured and their family, friends, and the community more broadly. Hence, the need to adopt a systems approach when developing road safety strategies and action plans that drive the implementation of efficacious countermeasures is clear. Given the scale of serious injury trauma, the implementation of high efficacy countermeasures that can influence a large proportion of the road trauma problem must be prioritised. This includes the further development and implementation of projected high efficacy countermeasures that were identified as being likely to be available in the short-to-medium term.

The need for proactive implementation of vehicle safety regulations and the implementation of driver-focussed and road infrastructure countermeasures is also clear. From an injury causation perspective, a key finding of the ECIS program was that the impact speeds at which crashes are occurring are well beyond the ability of the vehicle to protect occupants from serious injury. This *Report* outlines key opportunities to address this significant risk factor, thereby providing confidence to system operators on ways to manage this threat.

Whilst each driver has a role to play in how they use the road transport system, the critical role of vehicle manufacturers and governments in defining and operationalising the level of safety of the road transport system cannot be overstated. To achieve the long-term goal of eliminating serious injury, significant steps will need to be taken now by governments and vehicle manufacturers in order for future vehicles to have the key safety systems they require to protect occupants from injury. The level of safety afforded to drivers and other road users, is, however, critically dependent on 'built-in' safety of the road and road infrastructure. The analysis of contributing factors demonstrates that these two domains require urgent attention. The range of countermeasures identified in this *Report* highlights the opportunity for these contributing factors to be addressed.

To conclude, when the ECIS program was initiated, it was done so with the expectation of identifying measures that would, once implemented, reduce, and ultimately eliminate serious injury road crashes in Victoria. This *Report* serves this purpose. The insights presented in this Report, as well as those in *ECIS Reports 1, 2 and 3*, represent a unique opportunity to improve the safety of Victorian road users well into the future using data from crashes that occurred in Victoria. It is incumbent that every effort is made to utilise the findings well. Armed with this knowledge, it now falls to all relevant parties with an interest in preventing crashes and serious injury on our roads to act.

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APPENDIX A VEHICLE MOVEMENTS AND FACTORS BY ECIS CRASH TYPE PER THE INTEGRATED SAFETY CHAIN

APPENDIX TABLE A.1 BASE CODING HEURISTICS FOR ECIS CRASHES AT MIDBLOCK LOCATIONS USING THE INTEGRATED SAFETY CHAIN

CRASHES AT MIDBLOCK LOCATIONS					
ISC Phase	**TYPE A** **Depart carriageway to left (SVC)**	**TYPE B** **Depart carriageway to right (SVC)**	**TYPE C** **Head-on (curve) (MVC)**	**TYPE D** **Head-on (straight) (MVC)**	**TYPE E** **Strike parked vehicle on roadway**
Threats to Normal Driving	***H-V-E that pre-dispose to crash, or negatively impact ability to avoid (H-V apply to all; E is site specific to crash type)***				
	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: pavement, geometry; signs	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: pavement, geometry; signs	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: pavement, geometry; signs	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: pavement, geometry; signs	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: pavement, geometry; signs
Normal driving	1. The control of the vehicle by a driver in a manner that is responsive to the road environment, surrounding traffic and associated traffic flow, and other road users; includes being responsive to any potential threat, including that posed by another road user. 2. Compliance with all traffic laws, inclusive of compliance with and/or responding appropriately to traffic signs/signals (i.e., traffic lights) including advisory signs. Prerequisites of Normal Driving are: seat belt worn; driving within the speed limit; non-use (handling) of a mobile phone; driver not impaired indexed as: BAC within limit for licence class; the non-use of illicit drugs or abuse/non prescribed use of benzodiazepines and/or opioid-based analgesics; not excessively drowsy.				
Deviation from Normal driving: advise	***Shifts occur due to driver performance failures, health and driver state factors, and/or intentional/unintentional non-compliant behaviours; initial point of not meeting Normal Driving definition (except impairment – see Threats to Normal Driving); vehicle still within safety margin to avoid crash***				
	Move from safe travel path (due to): fail to recognise roadway cues (state factors, e.g., inattention)	Move from safe travel path (due to): fail to recognise roadway cues (state factors, e.g., inattention)	Move from safe travel path (due to): fail to recognise roadway cues (state factors, e.g., inattention)	Move from safe travel path (due to): fail to recognise roadway cues (state factors, e.g., inattention)	Move from safe travel path (due to): fail to recognise roadway cues (state factors, e.g., inattention)
Emerging situation: warning and support	***Vehicle sufficiently beyond deviation to represent direct threat to driver if left unchecked***				
	Drift/deviate/move from lane (due to fail to respond to roadway cues)	Drift/deviate/ move from lane AND crossed centre line (due to fail to respond to roadway cues)	Drift/deviate/move from lane (due to fail to respond to roadway and oncoming traffic cues)	Drift/deviate/move from lane (due to fail to respond to roadway and oncoming traffic cues)	Drift/deviate/move from lane (due to fail to respond to roadway and oncoming traffic cues)
Critical situation / crash imminent (intervene)	Entered shoulder/off roadway (from travel lanes) due to, e.g., slide / loss of vehicle control, or from non-response	Crossed into midline and right shoulder (from travel lane) due to, e.g., slide / loss of vehicle control or from non-response	Cross midline and into path of oncoming vehicle; due to, e.g., slide / loss of vehicle control, or from non-response. [also promote response from B-/other vehicle]	Cross midline and into path of oncoming vehicle; due to, e.g., slide / loss of vehicle control, or from non-response. [also promote response from B-/other vehicle]	Vehicle parked on left: travelling in lane of stationary vehicle, due to, e.g., slide / loss of vehicle control, or from non-response Vehicle parked right: crossed midline and travelling in lane of stationary vehicle.
Crash unavoidable / inevitable	Immediate pre-crash (time-to-collision: imminent) (all crash sub-types)				
Crash	Energy control: occupant protection and protection from roadside objects and rollover (tripping factors incl. high COG) (all crash sub-types)				

Notes:
a) Type A, B and C: object struck is beyond shoulder; Type E: crash into vehicle parked on carriageway (unoccupied).
b) SVC: single vehicle crash; MVC: multiple vehicle crash.
c) Compliance/non-compliance with speed limit falls within domain of *Deviation from Normal Driving.*
d) Crashworthiness applies at Crash Phase; impact speed relevant to energy control (crash), measured as being within/outside vehicle safety envelope/boundary condition (see Appendix B).
e) Emergency care and response (not shown, relevant to all crashes) – post-crash factors relate to extrication, vehicle position (access) and location from services.

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APPENDIX TABLE A.2 CODING HEURISTICS FOR ECIS CRASHES AT INTERSECTION LOCATIONS USING THE INTEGRATED SAFETY CHAIN

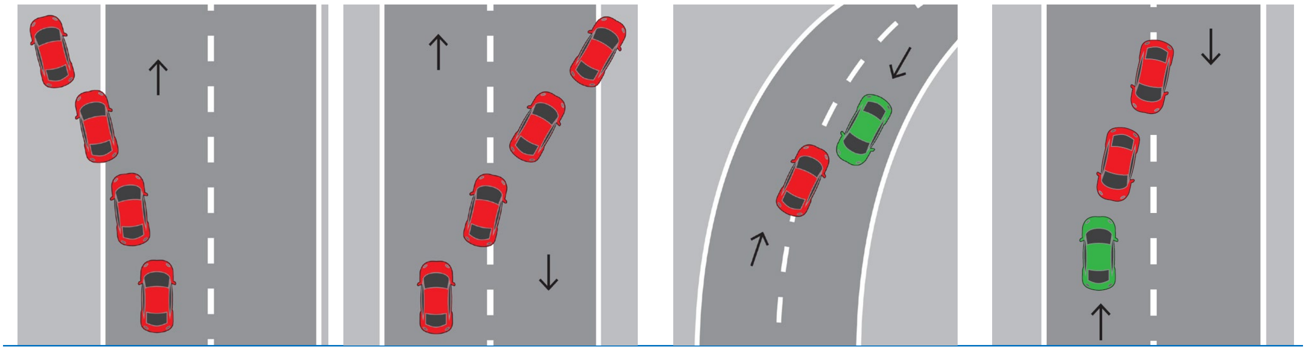
CRASHES AT INTERSECTION LOCATIONS				
ISC Phase	**TYPE F (F-1: unsignalized / F2: TCS)**	**TYPE G**	**TYPE H (H-1: TCS / H-2: unsignalized)**	**TYPE I**
	Enter carriageway	**Turn across**	**Cross-traffic**	**Rear impact (at intersections/in traffic)**
Threats to Normal Driving	*H-**V-E that pre-dispose to crash, or negatively impact ability to avoid (H-V apply to all; E is site specific to crash type)***			
	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: intersection layout misleading; sightlines to TCS, geometry, pavement, signs	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: intersection layout misleading; sightlines to TCS, geometry, pavement, signs	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: intersection layout misleading; sightlines to TCS, geometry, pavement; signs	H: impaired (intoxicated, illicit drugs, abuse prescription medication) medical/health condition, excessive fatigue, cognitive status, peer passenger, previous crash, traffic offence history; experiential (licence status) V: vehicle (roadworthy related) condition E: intersection layout misleading; sightlines to TCS, geometry, pavement, signs
Normal driving	1. The control of the vehicle by a driver in a manner that is responsive to the road environment, surrounding traffic and associated traffic flow, and other road users; includes being responsive to any potential threat, including that posed by another road user. 2. Compliance with all traffic laws, inclusive of compliance with and/or responding appropriately to traffic signs/signals (i.e., traffic lights) including advisory signs. Prerequisites of Normal Driving are: seat belt worn; driving within the speed limit; non-use (handling) of a mobile phone; driver not impaired indexed as: BAC within limit for licence class; the non-use of illicit drugs or abuse/non prescribed use of benzodiazepines and/or opioid-based analgesics; not excessively drowsy.			
Deviation from Normal driving: advise	***Shifts occur due to driver performance failures, health and driver state factors, and/or intentional/unintentional non-compliant behaviours; initial point of not meeting Normal Driving definition (except impairment – see Threats to Normal Driving); vehicle still within safety margin to avoid crash***			
	Apparent failure to observe / see TCS, (e.g., inattention) [in safety margin]	Apparent failure to observe / see TCS, e.g., inattention) [in safety margin]	Apparent failure to observe / see TCS, e.g., inattention) [in safety margin]	Apparent failure to observe / see TCS and / or presence of (or misjudged intent of) stationary vehicle
Emerging situation: warning and support	***Vehicle sufficiently beyond deviation to represent direct threat to driver if left unchecked***			
	Lack of appropriate response to TCS and/or oncoming vehicle (applies A-B vehicles; sudden event is vehicle in path)	Lack of appropriate response to TCS and/or oncoming vehicle (applies A-B vehicles; sudden event is vehicle in path)	Lack of appropriate response to TCS and/or oncoming vehicle (applies A-B vehicles; sudden event is vehicle in path)	Lack of appropriate response to TCS
Critical situation / crash imminent (intervene)	Entered/encroached intersection in path of vehicle	Entered/encroached intersection in path of vehicle	Entered/encroached intersection in path of vehicle	No response to being in path of stationary vehicle
Crash unavoidable / inevitable	Immediate pre-crash (time-to-collision: imminent) (all crash sub-types)			
Crash	Energy control: occupant protection and protection from roadside objects and rollover (tripping factors incl. high COG) (all crash sub-types)			

Notes:
a) TCS = traffic control signal, incudes traffic lights (note, fully controlled turns) and Stop/Give-way (yield) signs.
b) Type F, G, H are for crashes where moving vehicles hit within intersection; Type I is rear impact at intersections (vehicle occupied – stationary or turning).
c) Compliance/non-compliance with speed limit falls within domain of deviation from *Normal Driving*.
d) Crashworthiness applies at Crash Phase; impact speed relevant to energy control (crash), measured as being within/outside vehicle safety envelope/boundary condition (see Appendix B).
e) Emergency care and response (not shown, relevant to all crashes) – post-crash factors relate to extrication, vehicle position (access) and location from services.

APPENDIX B CRASH TYPES DEFINED AND NUMBER OF ECIS INJURED DRIVERS

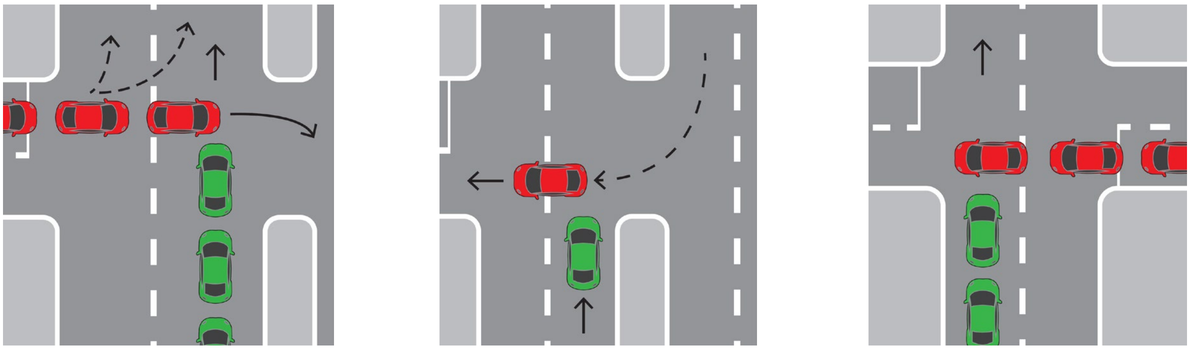
LANE DEPARTURE (OFF-PATH AND HEAD-ON)
[MAIS 1+: n = 202; MAIS 3*: n = 116]

OFF-ROAD TO LEFT (A)	OFF-ROAD TO RIGHT (B)	HEAD-ON ON CURVE (C)	HEAD-ON ON STRAIGHT (D)
(MAIS 1+: n = 68; 3+ n = 32)	(MAIS 1+: n = 60; 3+ n = 32)	(MAIS 1+: n = 19; 3+ n = 15)	(MAIS 1+: n = 55; 3+ n = 37)



ACROSS PATH
[MAIS 1+: n = 120; MAIS 3: n = 53]

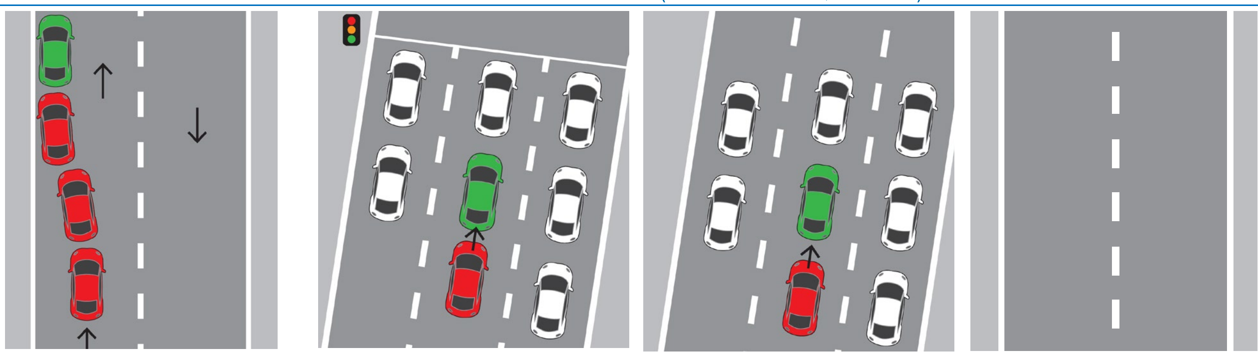
ENTER CARRIAGEWAY (F)	TURN ACROSS (G)	CROSS TRAFFIC (H)
(MAIS 1+: n = 43; 3+ n = 17)	(MAIS 1+: n = 21; 3+ n = 6)	(MAIS 1+: n = 56; 3+ n = 30)



REAR IMPACT
[MAIS 1+: n = 69; MAIS 3: n = 14]

OTHER (K)
[MAIS 1+: n = 9
MAIS 3: n = 5]

INTO PARKED VEHICLE (MIDBLOCK) (E)	AT INTERSECTION (I)	IN TRAFFIC (MIDBLOCK) (J)
(MAIS 1+: n = 25; 3+ n = 6)	(MAIS 1+: n = 27; 3+ n = 6)	(MAIS 1+: n = 17; 3+ n = 2)



APPENDIX FIGURE B.1 NUMBER OF INJURED ECIS CASE DRIVERS BY CRASH TYPE, BY INJURY SEVERITY*

Key: Vehicle (red): signifies the critical pre-crash vehicle movement; Vehicle (green): signifies that vehicle travelling in its normal path (or is stationary, rear impact - parked) and involved in the crash; Vehicle (white): vehicle (stationary or moving) in proximity of rear-impact crash but not involved. The ECIS driver can be the occupant of either of the crash-involved vehicles in each of the crash type scenarios. Note: * 3+ refers to MAIS 3+ injury severity. (*letter*) denotes crash type identifier.

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APPENDIX C SUPPLEMENTARY INFORMATION ON THE APPLICATION OF DRIVER-FOCUSSED COUNTERMEASURES TO MANAGE *THREATS TO NORMAL DRIVING* (ISC PHASE 1)

To the fullest extent possible, information concerning the scope of application and the intended application of each countermeasure is presented in the body of the *Report,* either within the text or in the Tables. This includes further explanatory information being provided as a *note* below each Table where required.

Due to the need for more detailed nature of the information and the structure of the Tables, it was not possible or practical to provide all relevant information for a particular multi-factorial countermeasure relating to impaired driving associated with alcohol (i.e., drink-driving) and drug use (i.e., drug-driving). This *Appendix* serves this purpose. It is expected that this will aid the reader in understanding the level of efficacy attributed to that countermeasure, as presented in the Tables.

This information is presented here solely to simplify the presentation of the Tables and to enhance the readability of the main body of the *Report.*

Contributing factor: Impaired driving due to the use of Alcohol and Other Drugs (AOD) (Section 3.1.5; Table 3.4) [ISC Phase: Threats-to-Normal Driving]

Countermeasure: **Enhanced management of Alcohol and Other Drug (AOD) offenders via an integrated risk-based sanction and behavioural intervention (inclusive of therapeutic management) multi-component approach**

This is expected to be a high efficacy countermeasure that could be available in the short-to-medium term. The estimated high efficacy rating is based on the implementation of a multi-component program that adopts a risk-based approach to the application of sanctions and behavioural interventions, inclusive of therapeutic management, to address drink-and drug-driving behaviour. This countermeasure services to complement the enforcement of drink-driving and drug-driving and associated public education programs.

This risk-focussed approach involves the implementation of a series of post-offence pathways based on BAC level and/or detected drug-type, as well as driving offence history (i.e., first-time offender, repeat offender). The model incorporates the dual use of the current range of sanctions under the current penalty regime (including technology-based solutions) and the tailored multi-component behavioural and therapeutic interventions that utilises monitoring and follow-up as appropriate. On-going monitoring and facilitation of the use of alternative transport modes may also be a feature of this model for a subset of offenders.

This countermeasure is premised on the emerging recognition that there is a need to take a holistic approach towards addressing impaired driving, particularly in light of complex factors frequently associated with repeat drink-driving and drug-driving. The intent is to adopt a more nuanced approach to the management of drink-driving and drug-driving offenders. The same general principles underpin the management of drivers known to misuse/abuse select prescription medications, hence the applicability of this type of intervention for this cohort of drivers (see Section 3.18; Table 3.5).

The countermeasure is primarily designed to address repeat offending behaviour through specific deterrence and management of underlying AOD use / medication misuse concerns. Current evidence suggests recidivism among the drink-driving[143] and drug-driving group(s) is between 25%[144] to 50%[145], with recidivism rates highest for users of methamphetamine.[146,147,148] The efficacy rating of *high* is based on both recidivism rates being less than 50%, and a further benefit of reducing current recidivism rates by at least 50%.

143 Fitzharris M, Liu S, Pieris S, Devlin A, Young K, Lenne M, Bowman D, Gatof J. Options to extend the coverage of alcohol interlock programs, Report AP-R495-15. Sydney: Austroads; 2015.

144 Mills L, Freeman J, Davey J. A study into the nature and extent of drug driving recidivism in Queensland (Australia). Journal of Safety Research. 2022; 81:116-122.

145 Mulvihill C., Liu S., Fitzharris M. MUARC Baseline program to assess the impact of drug use on road safety: Report 1 - Review of International literature on drug-driving and countermeasure opportunities. Clayton: Monash University Accident Research Centre; 2022.

146 Fitzharris M, Liu S, Newstead S. Estimation of the offence and crash reduction benefits of organisation-wide expansion of the Infringement at the Roadside (IaR) process to all first-time drug-driving offenders. Clayton: Monash University Accident Research Centre; 2009.

147 Horyniak D, Dietze P, Lenton S, Alati R, Bruno R, Matthews A, Breen C, Burns L. Trends in reports of driving following illicit drug consumption among regular drug users in Australia, 2007-2013: Has random roadside drug testing had a deterrent effect? Accident Analysis and Prevention. 2017 May; 104:146-155.

148 Liu S., Dietze P., Fitzharris M. MUARC Baseline program to assess the impact of drug use on road safety: Report 3 - Understanding the patterns and motivations for drug-driving behaviour: community attitudes towards addressing drug-driving in Victoria, Australia. Clayton: Monash University Accident Research Centre; 2020.

Behavioural and therapeutic interventions are designed to complement sanctions in this countermeasure model. Interventions are aimed at addressing behaviours that underpin the decision to drive, also recognising that the misuse of AOD can also be related to broader mental health conditions and addiction. A suite of behavioural and therapeutic interventions is expected to be implemented.

Currently available exemplar behavioural-focussed interventions include:

- Victoria's *Behaviour Change Program*. Participation is mandatory as part of the post-offence relicensing requirement (see https://www.vicroads.vic.gov.au/licences/drink-driving-drug-driving-and-excessive-speed-offences/behaviour-change-programs). This program is yet to be evaluated.
- The *Back On Track* (BOT) program (Ontario, Canada). The BOT program includes participation in an 8-hour education workshop or a 16-hour treatment workshop, with a follow-up at least 6-months after completion of the workshop.
    - An evaluation of the BOT program demonstrated a 21% reduction in drinking and driving recidivism.[149]
    - Participation in the BOT program has also been shown to reduce harmful use of alcohol and other drugs.[150]
- An example of a risk / severity-based program to manage recidivism can be found in Quebec, Canada. In a longitudinal follow-up study (3-years), completion of an intensive intervention and case management approach was associated with a 35% lower rate of recidivism for drivers with a multiple Driving-While-Under the Influence (DWI) offences relative to completion of a brief psycho-education intervention. The reduction in recidivism was higher for first-time DWI offenders (-57%). This result was in the context of low rates of DWI recidivism. The total sample size was 37,612 DWI offenders.[151]
- Court-based interventions and pre-trial services delivered under the umbrella of therapeutic justice models represent another promising approach to manage drink-driving and drug-driving offenders.[152]
    - Exemplar US-based program: El Paso Praxis Program, Texas Court System. Reference: Mr. Robert Anchondo, Judge, El Paso County Court. Keynote presentation at the 23rd International Council on Alcohol, Drugs and Traffic Safety (ICADTS) Conference. 28 Aug 2022 to 31 Aug 2022. Rotterdam, The Netherlands.

Monitoring through a case-management type approach and/or through the use of technology is a required feature of these combined sanction-behavioural-based therapeutic intervention models.

It is recognised that while alcohol interlock technology is available as a physical barrier to prevent drink-driving where fitted, such technology does not currently exist for drug-driving although impairment-based driver monitoring systems are under development. In these instances, monitoring can take different forms and can be embedded within behavioural interventions, therapeutic interventions (including case management approaches) and/or through other Court-supported processes.

The key design principle of the pathway countermeasure is that it adopts a nuanced risk-based approach that utilises both sanctions, behavioural and therapeutic interventions that incorporates monitoring tailored on need. Referred to a *pathways approach,* the countermeasure is applicable to manage drink-drivers, drug-drivers, and drivers impaired due to the misuse or abuse of certain prescribed medications (i.e., opioid analgesics; benzodiazepines).

It is acknowledged that this countermeasure model needs to be designed and trialled. MUARC is currently engaged in this work as part of the MUARC *Baseline Research Program*. Further significant development work is required; however, research from overseas suggests that this approach is highly promising.

With the optimal set of sanctions, behavioural and therapeutic interventions based on risk, with appropriate follow-up mechanisms as needed, this countermeasure is projected to have high efficacy in addressing impaired driving. Evaluations that assess the efficacy of this approach will be required. These evaluations must

149 Ma T, Byrne PA, Haya M., Elzohairy Y. Working in tandem: the contribution of remedial programs and roadside licence suspensions to drinking and driving deterrence in Ontario. Accident Analysis &Prevention, 2015: 85,248–256.

150 Wickens CM, Flam-Zalcman R, Stoduto G, Docherty C, Watson TM, van der Maas M, et al. The Impact of Remedial Programme Participation on Convicted Drinking Drivers' Alcohol and Other Drug Use 6 Months Following Programme Completion. International Journal of Mental Health and Addiction. 2018;16(3):598-616.

151 Brown TG, Moxley-Kelly N, Ouimet MC. Recidivism prevention for impaired driving: Longitudinal 5-year outcomes from Quebec's severity-based intervention assignment program. Journal of Substance Abuse Treatment. 2022;142:108855.

152 Hora, Schma, Rosenthal, Therapeutic jurisprudence and the drug treatment court movement: revolutionizing the criminal justice system's response to drug abuse and crime in America. Notre Dame Law Review, 1999.

include an assessment of the individual components of the countermeasure so that the incremental effectiveness and contribution of each element to the overall countermeasure package can be understood.

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APPENDIX D IMPACT SPEED VEHICLE SAFETY LIMITS

APPENDIX TABLE D.1 HEURISTICS FOR THE ASSESSMENT OF IMPACT SPEED (KM/H) AND VEHICLE SAFETY LIMITS (BOUNDARY CONDITIONS) BY ANCAP STAR RATING

IMPACT TYPE	VEHICLE TYPE / COLLISION PARTNER	ANCAP STAR-RATING AND THRESHOLD IMPACT SPEED (KM/H)				
		5	4	3	2	1
Frontal – fully distributed	Passenger car/Fixed object	<65 (either A† or B‡)	<55	<50	<40	<30
Frontal offset	Passenger car/Fixed object	<64 (either A or B)	<50	<40	<30	<30
Frontal narrow offset	Passenger car/Fixed object	<40 (either A or B)	<30	<30	<20	<20
Side oblique/sideswipe, rollover	Passenger car/Fixed object	<50 (B for A; A for B)	<40	<30	<20	<20
Side oblique	4WD/Van	<40 (B for A; A for B)	<30	<20	<20	<20
Side oblique	Truck/Bus	<20 (B for A; A for B)	<10	<10	<10	<10
Side pole/fixed object	Single vehicle crash	<30	<20	<15	<10	<10
Rear	Speed differential for vehicles: 20 km/h (all vehicles)					

ANCAP rules for vehicles not rated, star-rating based on year of manufacture (based on average): pre-1990; 1: 1990-1999; 3: 2000-2009; 4: 2010-2013; 5: 2014+
† A: refers to ECIS case vehicle; ‡B: refers to non-case/other vehicle; highest speed used for frontal impacts; bullet vehicle speed used for side impact crashes
Source: Modified from ECIS Safe System-2 Workshop, 2016 (Melbourne) with acknowledgement of Professor Claes Tingvall and Dr Anders Lie.

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APPENDIX E DATA ON MANAGING IMPACT SPEED THROUGH SPEED LIMIT REDUCTIONS FOR CRASHES WHERE THE SAFETY ENVELOPE OF THE VEHICLE WAS EXCEEDED

The data presented in Table E.1 and E.2 shows the number and percent of urban and rural crash locations where a speed limit reduction was identified as a countermeasure to reduce impact speed. This relates to the data showing the 67.3% of crashes (n = 269 of 400; MAIS 3+: 80.3%, 151 of 188) occurred at an impact speed outside the vehicle safety envelope, based on primary impact point and NCAP star-rating (see Section 5.1.4).

The intention is to provide the reader with further information on the speed limit of roads where these crashes occurred. The data includes crashes of all configurations, including frontal impact crashes, side impact crashes and rear impact crashes. A strong dose-response effect is evident; this is, as the speed limit increases, so too does the proportion of locations where a reduction in the speed limit was identified as the mechanism to bring the impact speed within the safety envelope of the vehicle.

It is worth noting that on 100-110 km/h speed limited roads, frontal impacts were dominant. These crashes were characterised by long sight distances, allowing braking to occur; hence, there were somewhat fewer locations where a speed limit reduction was identified as being required. As shown in *ECIS Report 1* and *ECIS Report 2*, the reduction in pre-crash speed was insufficient to protect most occupants from serious injury.

APPENDIX TABLE E.1 NUMBER OF CRASH LOCATIONS WHERE A SPEED LIMIT REDUCTION WAS IDENTIFIED AS BEING A COUNTERMEASURE TO REDUCE IMPACT SPEED

MAIS 1+	URBAN			RURAL			ALL		
SPEED LIMIT (km/h)	NO CHANGE	REDUCE	NUMBER	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL
<= 60	65	53	118	9	10	19	74	63	137
70	10	27	37	0	2	2	10	29	39
80	23	46	69	3	12	15	26	58	84
90	0	1	1	0	4	4	0	5	5
100-110	7	21	28	14	93	107	21	114	135
Total	105	148	253	26	121	147	131	269	400

MAIS < 3	URBAN			RURAL			ALL		
SPEED LIMIT (km/h)	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL
<=-60	49	25	74	3	2	5	52	27	79
70	6	16	22	0	1	1	6	17	23
80	22	25	47	2	5	7	24	30	54
90	-	-	-	0	1	1	0	1	1
100-110	4	12	16	8	31	39	12	43	55
Total	81	78	159	13	40	53	94	118	212

MAIS 3+	URBAN			RURAL			ALL		
SPEED LIMIT (km/h)	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL
<=-60	16	28	44	6	8	14	22	36	58
70	4	11	15	0	1	1	4	12	16
80	1	21	22	1	7	8	2	28	30
90	0	1	1	0	3	3	0	4	4
100-110	3	9	12	6	62	68	9	71	80
Total	24	70	94	13	81	94	37	151	188

APPENDIX TABLE E.2 PERCENT OF CRASH LOCATIONS WHERE A SPEED LIMIT REDUCTION WAS IDENTIFIED AS BEING A COUNTERMEASURE TO REDUCE IMPACT SPEED

MAIS 1+	URBAN			RURAL			ALL		
SPEED LIMIT (km/h)	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL
<=-60	55.1%	44.9%	100%	47.4%	52.6%	100%	54.0%	46.0%	100%
70	27.0%	73.0%	100%	0.0%	100.0%	100%	25.6%	74.4%	100%
80	33.3%	66.7%	100%	20.0%	80.0%	100%	31.0%	69.0%	100%
90	0.0%	100.0%	100%	0.0%	100.0%	100%	0.0%	100.0%	100%
100-110	25.0%	75.0%	100%	13.1%	86.9%	100%	15.6%	84.4%	100%
Total	41.5%	58.5%	100%	17.7%	82.3%	100%	32.8%	67.3%	100%

MAIS < 3	URBAN			RURAL			ALL		
SPEED LIMIT (km/h)	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL
<=-60	66.2%	33.8%	100%	60.0%	40.0%	100%	65.8%	34.2%	100%
70	27.3%	72.7%	100%	0.0%	100.0%	100%	26.1%	73.9%	100%
80	46.8%	53.2%	100%	28.6%	71.4%	100%	44.4%	55.6%	100%
90	-	-	-	0.0%	100.0%	100%	0.0%	100.0%	100%
100-110	25.0%	75.0%	100%	20.5%	79.5%	100%	21.8%	78.2%	100%
Total	50.9%	49.1%	100%	24.5%	75.5%	100%	44.3%	55.7%	100%

MAIS 3+	URBAN			RURAL			ALL		
SPEED LIMIT (km/h)	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL	NO CHANGE	REDUCE	ALL
<=-60	36.4%	63.6%	100%	42.9%	57.1%	100%	37.9%	62.1%	100%
70	26.7%	73.3%	100%	0.0%	100.0%	100%	25.0%	75.0%	100%
80	4.5%	95.5%	100%	12.5%	87.5%	100%	6.7%	93.3%	100%
90	0.0%	100.0%	100%	0.0%	100.0%	100%	0.0%	100.0%	100%
100-110	25.0%	75.0%	100%	8.8%	91.2%	100%	11.3%	88.8%	100%
Total	25.5%	74.5%	100%	13.8%	86.2%	100%	19.7%	80.3%	100%

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APPENDIX F EFFECT OF SUBSTITUTION OF A 5-STAR SAFETY RATED VEHICLE ON IMPACT SPEED EXCEEDING THE SAFETY ENVELOPE OF THE VEHICLE

APPENDIX TABLE F.1 ALTERNATIVE SCENARIO REGARDING VEHICLE SAFETY ENVELOPE, IMPACT SPEED AND INJURY SEVERITY: EFFECT OF VEHICLE SUBSTITUTION TO A 5-STAR SAFETY RATED VEHICLE

SSE†	FACTOR/EVENT/ACTION	ALL				LANE DEPARTURE				ACROSS PATH				REAR IMPACT				OTHER			
		MAIS 1+ (N = 400)		MAIS 3+ (N = 188)		MAIS 1+ (N = 202)		MAIS 3+ (N = 116)		MAIS 1+ (N = 120)		MAIS 3+ (N = 53)		MAIS 1+ (N = 69)		MAIS 3+ (N = 14)		MAIS 1+ (N = 9)		MAIS 3+ (N = 5)	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Phase 7: Crash (relevant to ECIS driver only unless indicated)																					
Alternative scenarios																					
Safety envelope impact speed metrics: Effects of fleet change to 5-star rated vehicles (Note: 181 = n = 37, 5-star + n = 144, <=4-star)																					
V†‡	Drivers in vehicles where impact speed is **within** vehicle safety envelope; includes drivers in 5-star vehicles + in ≤ 4-star vehicles where 5-star impact speed threshold was used (always within/changed to within due to 5-star impact speed threshold used)	219	54.8%	81	43.1%	102	50.5%	51	44.0%	72	60.0%	23	43.4%	39	56.5%	3	21.4%	6	66.7%	4	80.0%
V	Drivers in vehicles where impact speed **exceeds** vehicle safety envelope; includes drivers in 5-star vehicles + in ≤ 4-star vehicles where 5-star impact speed threshold was used (always/continue to exceed)	181	45.3%	107	56.9%	100	49.5%	65	56.0%	48	40.0%	30	56.6%	30	43.5%	11	78.6%	3	33.3%	1	20.0%
Safety envelope impact speed metrics for ≤ 4-star safety rated vehicles using 5-star vehicle impact speed threshold (indicates 'what-if' all drivers in 5-star safety-rated vehicles) (Note: n = 78 + n = 88 + n = 144 => 310, i.e., <=4-star vehicles]																					
V	Impact speed remains **within** (no change) vehicle safety envelope using 5-star vehicle impact speed	78	19.5%	24	12.8%	26	12.9%	11	9.5%	32	26.7%	11	20.8%	18	26.1%	0	0.0%	2	22.2%	2	40.0%
V	Impact speed **now within** vehicle safety envelope using 5-star vehicle impact speed thresholds	88	22.0%	44	23.4%	57	28.2%	31	26.7%	20	16.7%	9	17.0%	8	11.6%	2	14.3%	3	33.3%	2	40.0%
V	Impact speed still **exceeds** vehicle safety envelope, despite using 5-star vehicle impact speed thresholds	144	36.0%	90	47.9%	83	41.1%	54	46.6%	37	30.8%	26	49.1%	21	30.4%	9	64.3%	3	33.3%	1	20.0%
For Reference only																					
V	Drivers in 5-star safety rated vehicle	90	22.5%	30	16.0%	36	17.8%	20	17.2%	31	25.8%	7	13.2%	22	31.9%	3	21.4%	1	11.1%	0	0.0%
V	Drivers in vehicle non-5-star safety rated vehicle	310	77.5%	158	84.0%	166	82.2%	96	82.8%	89	74.2%	46	86.8%	47	68.1%	11	78.6%	8	88.9%	5	100%

† SSE: Safe System Element; ‡ V: Vehicle. Note: assessment of whether impact speed is within or exceeds the vehicle safety envelope is based on impact point, collision partner, and NCAP star-rating, see Appendix D.

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APPENDIX G ECIS REPORT SERIES

The findings of the ECIS program are presented across four Reports. These *Reports* are available at the MUARC website.

ECIS REPORT 1 **OVERVIEW AND ANALYSIS OF CRASH TYPES, INJURY OUTCOMES AND CONTRIBUTING FACTORS**

This report provides the rationale for the ECIS program, and a description of the study methods and key findings. Findings include details of the crashes and injury outcomes overall and by crash type, an analysis of contributing factors for both crash occurrence and injury severity, and a detailed examination of the safety of Victoria's road transport system as it applies to drivers and occupants of passenger vehicles. This Report aims to provide a comprehensive understanding of serious injury crashes. The findings form the basis of identifying future road safety countermeasures aimed at eliminating serious injuries.

ECIS REPORT 2 **SPEED, CRASH RISK AND INJURY SEVERITY**

This report examines the role of speed in shaping crash risk and injury severity. The report examines five key questions: 1. The relationship between the speed limit and travel speed; 2. The relationship between travel speed and the risk of involvement in a crash that results in one or more involved drivers being hospitalised; 3. The relationship between travel speed and vehicle speed at impact, the frequency of pre-crash avoidance actions and the effect, if any, of these actions on the speed of the vehicle at impact; 4. The relationship between impact speed and injury severity, and 5) The injury reduction benefit of lower impact speeds. A case series approach was used to illustrate the potential benefits of reduced travel speed, speed limit compliance and impact speed on crash and injury severity outcomes.

Key inputs to this analysis are the estimates of travel speed and impact speed obtained through the crash reconstruction process and the 'free travel speed' data obtained from ECIS Control Study drivers.

The Report presents practical examples of the effect of reducing travel speed on crash outcomes using crash reconstruction methods.

ECIS REPORT 3 **UNDERSTANDING CONTRIBUTING FACTORS FOR SERIOUS INJURY CRASHES USING CRASH CHAIN ANALYSIS**

This report aims to highlight key safety gaps and trauma risk in the road transport system in Victoria that lead to serious injury. The focus of the report is two-fold: 1. identifying factors associated with serious injury crashes occurring, and 2. identifying factors associated with serious injury, given that a crash occurs. Analysis is presented by crash type using a road trauma '*integrated safety chain*' model developed during the ECIS program. The Report sets the basis for ECIS Report 4.

ECIS REPORT 4 **IDENTIFICATION OF COUNTERMEASURES TO ADDRESS SERIOUS INJURY CRASHES**

This report identifies interventions and actions aimed at reducing the incidence of serious injury sustained in crashes in Victoria. Interventions are focussed on short-to-medium term actions, as well as setting a path towards the longer-term vision of creating an inherently safe road transport system. Countermeasures are presented across the phases of the crash, from before a driver enters a vehicle through to recovery from injuries sustained in the crash. This analysis highlights where, and by what means, reductions in serious injury can be achieved.

Further information

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