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Application of a modified Integrated Safety Chain (ISC) to identify opportunities to address serious injury crashes through active safety systems

Michael Fitzharris[1], Mike Lenné[1], Sara Liu[1], Tandy Pok Arundell[1], Sujanie Peiris[1], Claes Tingvall[1 2], Bruce Corben[3], Diana Bowman[4], Andrew Morris[5]

1. Monash University Accident Research Centre, Australia
2. AFRY, Sweden
3. Corben Consulting, Australia
4. Arizona State University, United States
5. Loughborough University, United Kingdom

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Outline of presentation

1. Context: Road trauma, future goals and evidence.
2. The real-world as a laboratory.
3. Frameworks for the analysis of in-depth data.
4. Base crash types (use cases).
5. Linking crash contributing factors to countermeasures: ‘safety need’.
6. Example 1: Contribution of distraction, drowsy driving and sudden sickness to serious injury crashes and countermeasures to address.
7. Example 2: Contributing factors at intersections and countermeasures.
8. Conclusions and Future Opportunities.

Context

- Inspired by *Vision Zero* and based in the *Safe System approach,* the Victorian Government (Australia) set ambitious targets in the 2021-2030 Road Safety Strategy.
  - By 2050, eliminate deaths and very serious injuries.
  - By 2030, halve road deaths by 2030 and progressively reduce serious injuries.
  - Builds on earlier Towards Zero based strategies.
- Current situation:
  - Number killed (2022): 241, with 127 (52.6%) being occupants of passenger vehicles.
  - Number seriously injured (2021): 5787 hospitalized with 645 having a length of stay >14 days.
- Key principle of the Strategy: Guided by evidence, make gains using all available current tools and laying the foundation for future technology implementation.
- **Common questions:**
  1. **Where will the safety gains come from?**
  2. **What is the 'safety need' for specific safety measures and technologies?**

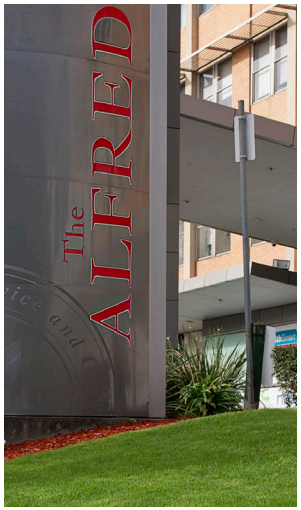
Creating the evidence-base: The ECIS program

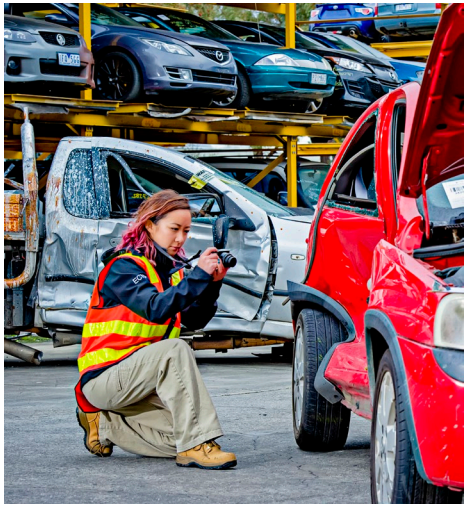
- To create the evidence base, the *Transport Accident Commission (TAC),* Victoria's no-fault government insurer, funded the *Enhanced Crash Investigation Study (ECIS).*
- In-depth crash investigation study, with a focus on 400 drivers hospitalised in a major trauma centre in the period 2014 to 2016 (sampling weight: 1:17; 18 – 93 years; 55% male; 37% rural; 47% MAIS 3+).
- Two objectives:
  1. Determine the factors associated with crash occurrence and injury severity.
  2. Identify crash prevention safety countermeasures and measures to prevent occupants of vehicles being seriously injured.

Operationalising the *data: From contributing factors to countermeasures*

- Substantial data collected using purpose-built data collection *Driver, Vehicle, Road* forms.
  - All medical information collected, and crashes reconstructed using HVE and/or PC-Crash to derive travel speed and collision metrics, as well EDR data where available.
- Synthesised each crash to determine presence or absence of factors across the human, vehicle and road environment that contributed to crash occurrence and injury severity.

Systematic approaches are needed for the identification of safety need of countermeasures across defined crash types.

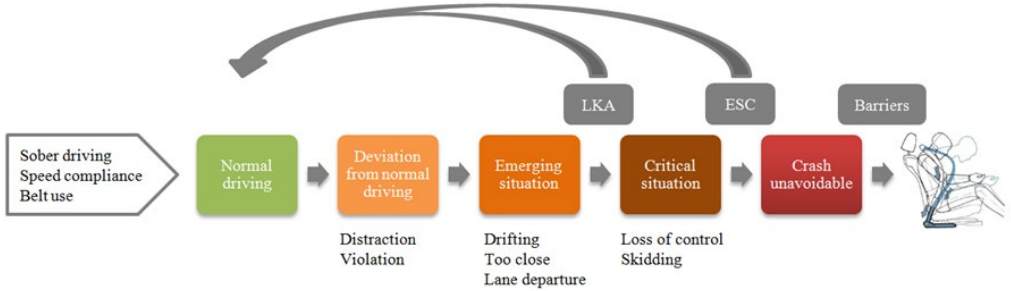




Systematic data-driven approaches: The need for frameworks

- Tingvall recognized that emerging vehicle safety systems blurred the *Haddon Matrix* HVE boundaries, shifting from passive safety to dynamic integrated safety systems that linked driver responses to the vehicle, linked the vehicle to the road environment, and better prepared the driver for the crash.

- The 'driving process model', or the Integrated Safety Chain (ISC), which as a time-based model Partitions the pre-crash phase into sub-phases.



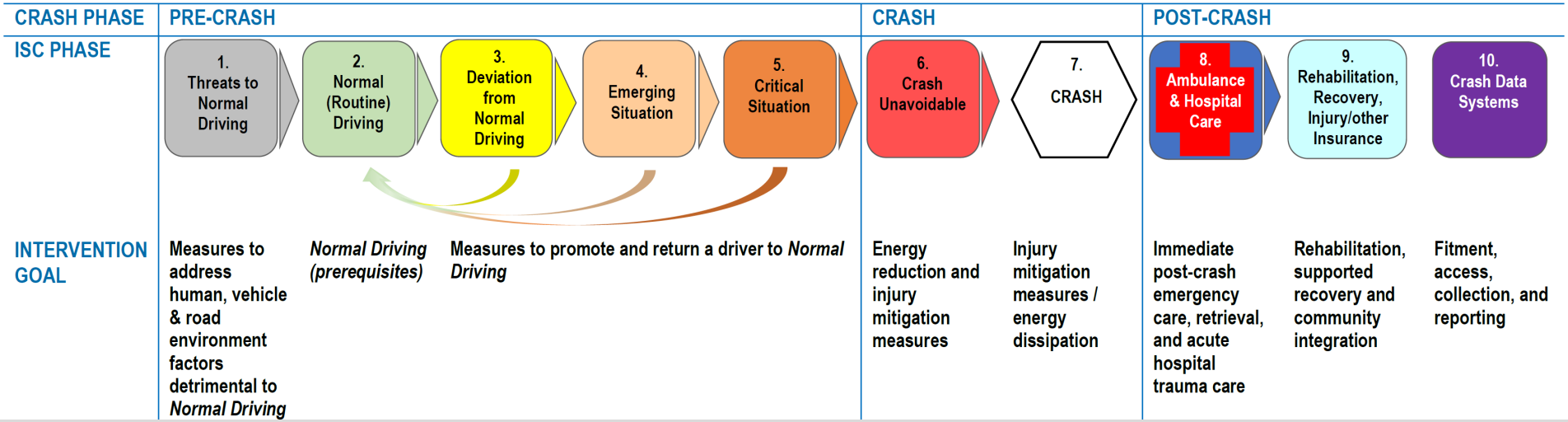
(TINGVALL, 2008 WITH ADAPTATIONS FROM LIE, 2012 & STRANDOTH, 2012)

- **The goal is to prevent progression from *Normal Driving* through the crash sequence to an unavoidable crash where reliance on passive safety injury prevention measures is absolute.**
- **Each phase represents an intervention point, given known risk (contributing) factors**

- The ISC has been used by a number of influential researchers in a range of contexts (e.g., Stigson, Rizzi, Strandroth, Lie, Sunnevång)

The expanded ECIS Integrated Safety Chain (ISC)

- Analysis of contributing factors using *Safe System Failure Analysis (SSFA).*
- After extensive development work, a 10-phase ISC model was developed.
  - Key principles and decision rules / heuristics were established for each phase, allowing consistent application using a 'case-by-case' approach.
  - Driver, vehicle and road infrastructure contributing (risk) factors were aligned to a crash phase.
  - 268 HVE current and future countermeasures were paired to specific contributing factors with measures appearing only once.
  - *Operationalised as the ECIS Safe System Decision Support Tool (ECIS-DST).*



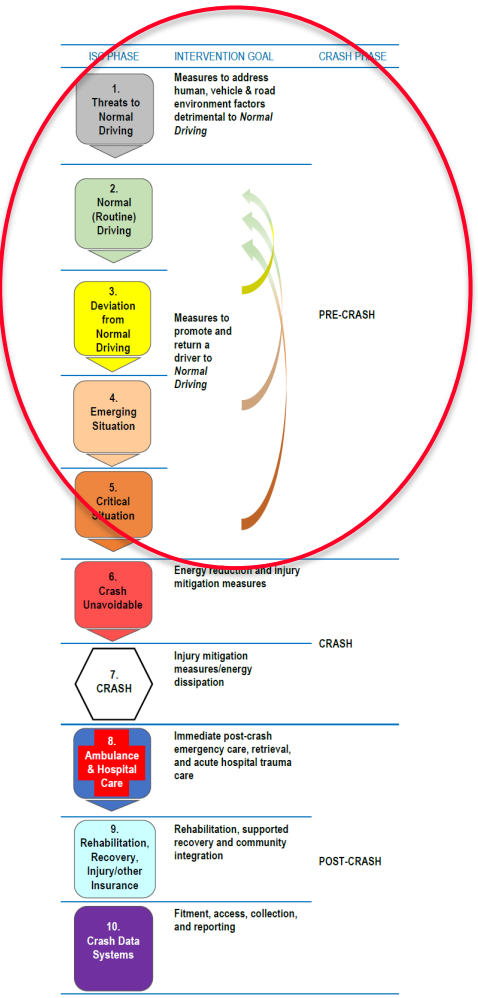
The concept and importance of *Normal Driving*

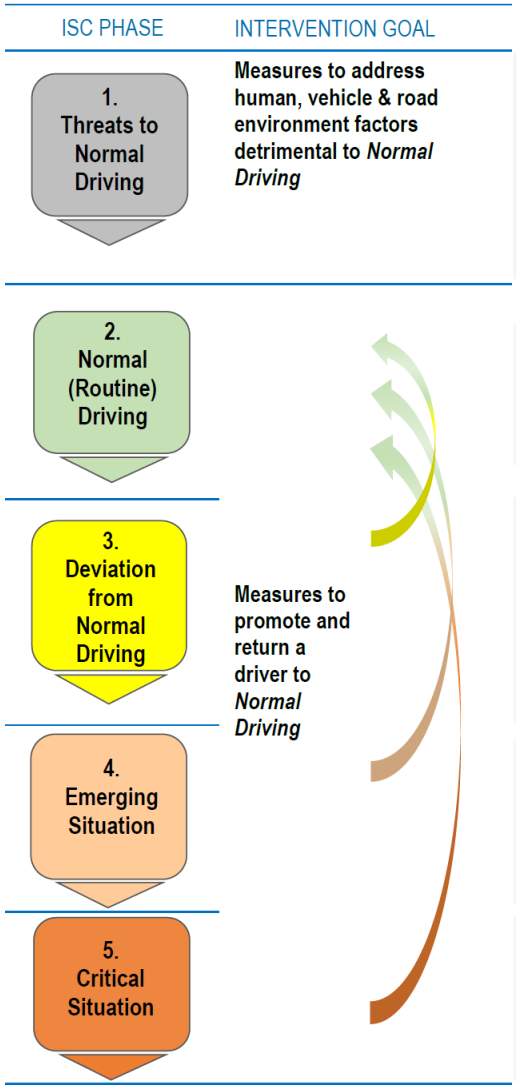
- Tingvall's ISC commences with *Normal Driving.*
  - Also referred to as: 'baseline, routine, and uneventful driving', 'benign and uneventful driving', and 'safe driving'. This is the 'non-conflict' phase of a trip.
- ECIS defined *Normal Driving* is defined as:

> 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 to that posed by another road user. *Normal Driving* is therefore highly contextual, **and**
>
> Compliance with all traffic laws, inclusive of compliance with and/or responding appropriately to traffic signs/signals (i.e., traffic lights) including advisory signs.
>
> Fundamental prerequisites of *Normal Driving* are the *Safe Driver* criteria. Drivers must be encouraged, supported, and/or compelled to comply.

- Key points regarding *Normal Driving*
  - The ISC **explicitly** recognises that deviations from *Normal Driving* occur due to **performance failures** (e.g., error, unsafe manoeuvre, driving adverse to conditions; inattention), **health and driver state factors**, and/or **intentional/unintentional non-compliant behaviours**.
  - Vehicle technology and infrastructure-based safety measures can play an important role in **supporting the driver** keeping within the bounds of *Normal Driving*
  - *Threats-to-Normal Driving* formally recognises that specific driver (e.g., effects of alcohol), vehicle (e.g., tyre condition), and infrastructure (e.g., pavement surface) threats that exist **prior to the commencement of a trip.**

Pre-crash risk factors and countermeasure opportunities





- Includes 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.
- **Intervention approach**: Eliminate the presence or manage the influence of these threats.

- *Normal Driving* –the proportion of crashes where defined prerequisites for *Safe Driving* were met (seat belt worn, not exceed speed limit, not using (holding) phone; not impaired (drugs, alcohol, S8 medicines), not excessively drowsy

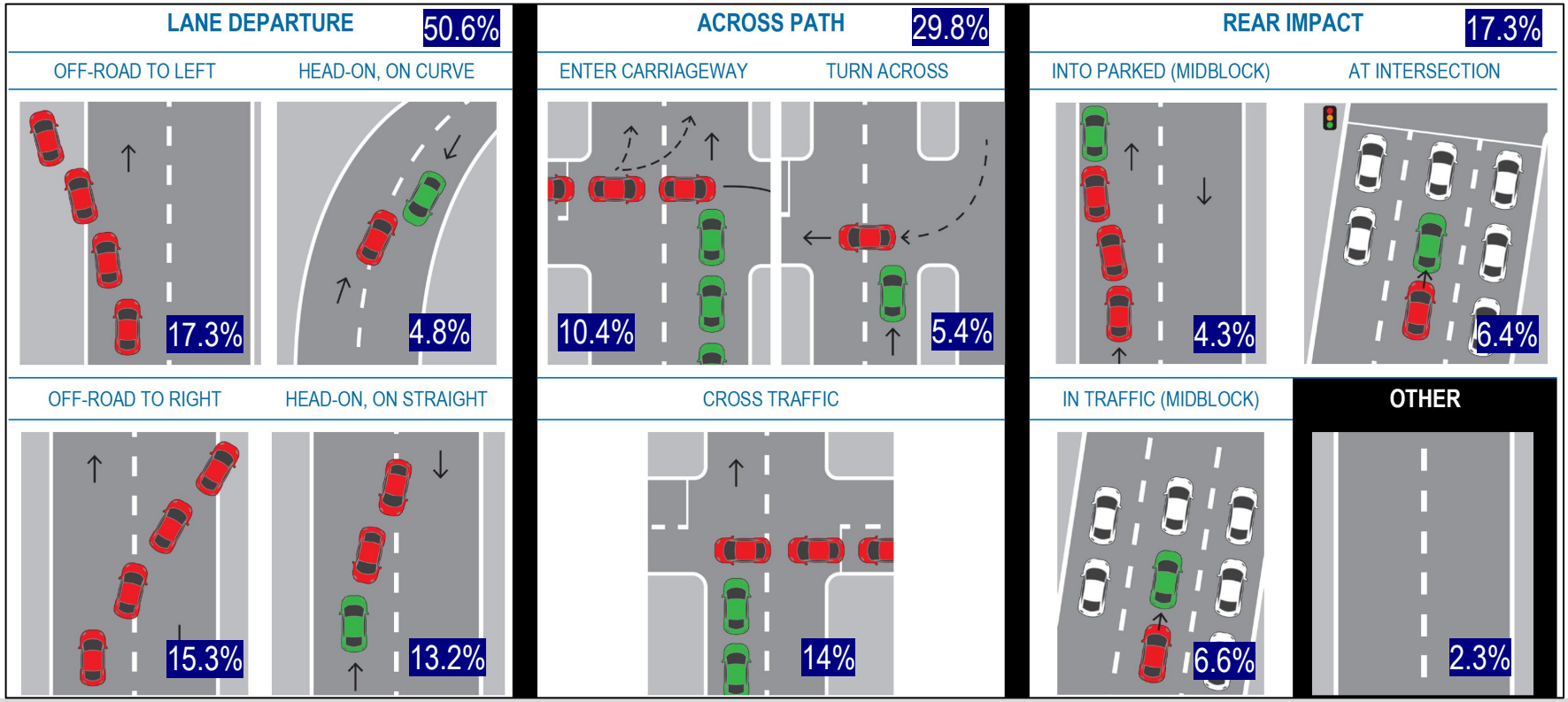
- Driver-based factors that result in a departure from the definition of *Normal Driving (excluding Threats).* Factors can result in failure to recognise roadway cues and presence of other road users/objects
- **Intervention approach***:* Promote and support a return to *Normal Driving* through information and warnings

- 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.
- **Intervention approach**: Warning and intervention in driving.

- 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

Base crash types

- Ten crash types (+ Other) were defined based on vehicle movement and conflict.
- For intersection (Across Path) crashes, subtypes based on presence/absence of traffic controls.
- Basis of analysing crash occurrence contributing factors and pre-crash countermeasures.



Primary analysis outcomes: contributing factors and countermeasures

- **Defined the proportion of injured drivers** where each contributing factor (Av: 181; Bv: 82) was **present and influenced the crash.**
- Basis of understanding of the contribution of each factor to serious injury road trauma, and provides the basis for crash specific countermeasures to be identified.

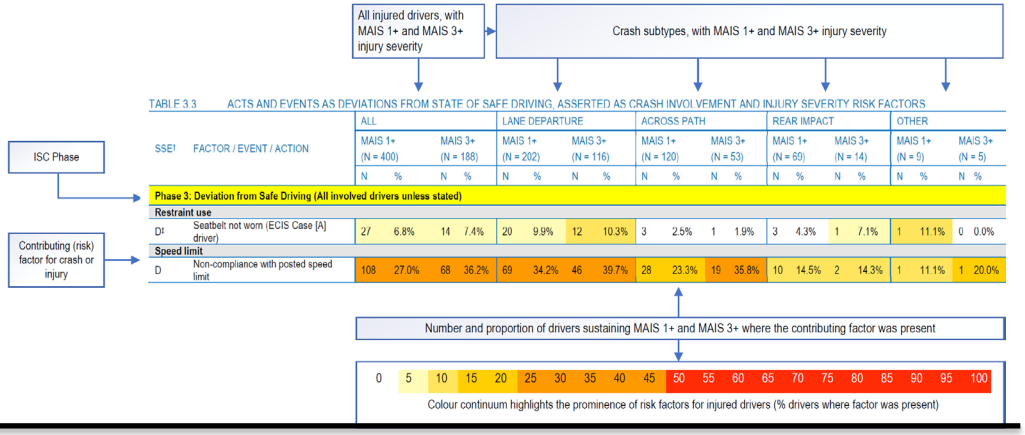


TABLE 3.3 ACTS AND EVENTS AS DEVIATIONS FROM STATE OF SAFE DRIVING, ASSERTED AS CRASH INVOLVEMENT AND INJURY SEVERITY RISK FACTORS

SSE†	FACTOR / EVENT / ACTION	ALL MAIS 1+ (N = 400)	ALL MAIS 3+ (N = 188)	LANE DEPARTURE MAIS 1+ (N = 202)	LANE DEPARTURE MAIS 3+ (N = 116)	ACROSS PATH MAIS 1+ (N = 120)	ACROSS PATH MAIS 3+ (N = 53)	REAR IMPACT MAIS 1+ (N = 69)	REAR IMPACT MAIS 3+ (N = 14)	OTHER MAIS 1+ (N = 9)	OTHER MAIS 3+ (N = 5)
		N %	N %	N %	N %	N %	N %	N %	N %	N %	N %
Phase 3: Deviation from Safe Driving (All involved drivers unless stated)											
Restraint use											
D‡	Seatbelt not worn (ECIS Case [A] driver)	27 6.8%	14 7.4%	20 9.9%	12 10.3%	3 2.5%	1 1.9%	3 4.3%	1 7.1%	1 11.1%	0 0.0%
Speed limit											
D	Non-compliance with posted speed limit	108 27.0%	68 36.2%	69 34.2%	46 39.7%	28 23.3%	19 35.8%	10 14.5%	2 14.3%	1 11.1%	1 20.0%

- **Analysis outcome: proportion of hospitalised drivers that each countermeasure will influence.**
- Terminology:
  - A countermeasure is **applicable** to a crash/injury based on if the function of the countermeasure addresses an observed contributing factor (i.e., Hence, crash/injury is '**sensitive**' to the action of the countermeasure.
- Key points:
  - Countermeasure library (268 possible measures).*
  - Countermeasure (intervention) categories (HVES, subtypes).
  - Efficacy ratings: low <20%, medium: 20-50%; high: 50%+.
  - Time Horizon:
    Now, short-term: within 5-years, medium-term: 5+ years.

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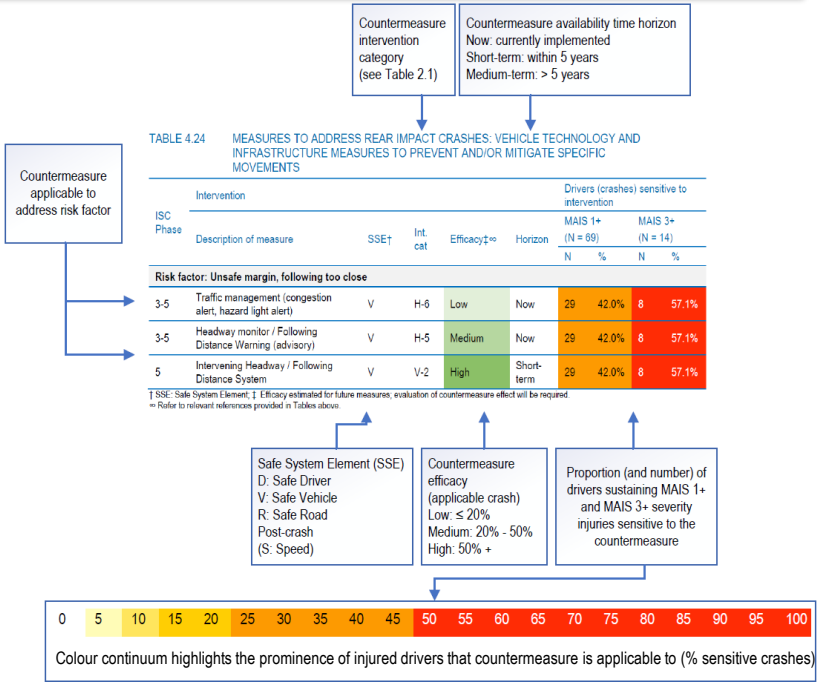


Vehicle tech. to address distraction, drowsy driving and sudden sickness

System / countermeasure	Contributing Factor being addressed	Applicable serious injury crashes (%)		Efficacy	Horizon
		MAIS 1+	MAIS 3+		
Attention Assist (warning)	Inattention – distraction inside/outside of vehicle/phone use	48.8%	50.0%	Low	Now
	Drowsy driving	24.5%	26.6%	Low	Now
Attention assist (warn) / Driver monitoring system (camera-based)	Inattention – distraction inside/outside of vehicle/phone use	48.8%	50.0%	Medium	Short-term
	Drowsy driving	24.5%	26.6%	Medium	Short-term
Attention assist (intervening with steer assist) / Driver monitoring system (camera-based)	Drowsy driving	24.5%	26.6%	High	Short-term
	Sudden sickness	10.0%	9.0%	High	Short-term
Attention Assist via DMS / OSM with vehicle takeover (steer, park) for a non-responsive driver)	Drowsy driving/asleep	11.0%	13.3%	High	Medium-term
	Sudden sickness	10.0%	9.0%	High	Medium-term
Disengage cruise control linked to Attention Assist, using DMS / OSM	Cruise control active and assessed to be contributing factor for crash event and/or associated with injury severity	2.8%	2.7%	High	Medium-term

Vehicle technology to address intersection crashes (selected)

System / countermeasure	Contributing Factor being addressed	Applicable serious injury crashes (%)		Efficacy	Horizon
		MAIS 1+	MAIS 3+		
Traffic sign display (in-vehicle)	Apparent failure to see / recognise /obey traffic signs at intersection	11.5%	12.2%	Medium	Now
Cross Traffic Alert (collision warning)	Enter intersection across path of vehicle	19.3%	20.2%	Medium	Now
Active Brake Assist with cross-traffic function / Junction AEB (optimised with sensor based on V2V)	Enter intersection across path of vehicle	19.3%	20.2%	High	Short-term
Intelligent Traffic Light Assist (haptic feedback of accelerator pushback + braking, V2V / V2I)	Driver failed to obey a red light at intersection, entered	8.3%	7.4%	High	Medium-term
Autobrake – forward (linked to DMS-OSM for non-responsive drivers)	Drift / roll into intersection (from stationary)	0.8%	1.6%	High	Medium-term

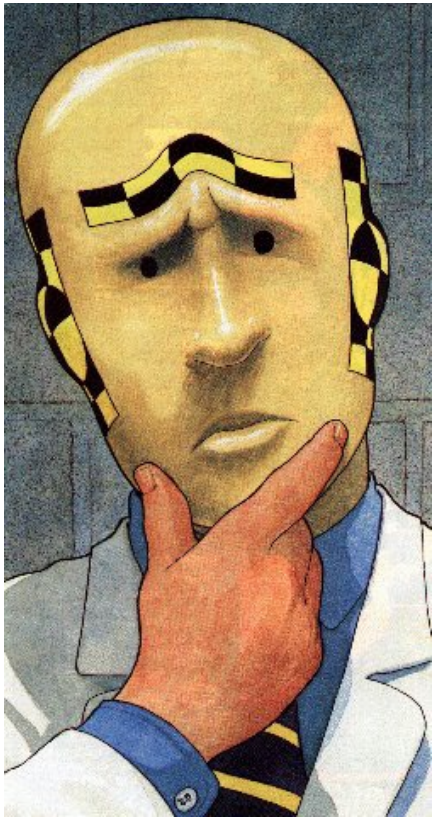
Conclusions (1)

- In-depth crash data is a very rich source, however systematic analysis methods are required to seek maximum value.
- In our in-depth study, we developed a series of data collection and analytical approaches to address the challenge of operationalising the *Safe System.*
- The ISC represents a valuable framework to facilitate analysis of in-depth data to drive current and future intervention priorities, based on known contributing factors across the entire crash sequence.
- Understanding where in in the crash sequence to intervene is key:
  - The vehicle and road infrastructure play an increasingly important role towards the 'back-end' of the pre-crash phases of the ISC.
  - Passive safety and post-crash response remain critical to address and improve.

Conclusions (2) and future opportunities

- The ISC facilitates the enumeration of the safety need for the full range of driver, vehicle and road infrastructure countermeasures, and highlights the need for their integration to be identified to address serious injury crashes.
- Findings can be used support the development and implementation of vehicle technology by government and industry.
- High and medium efficacy measures ought to be encouraged through through R&D investment and regulatory action where appropriate.
- Recommend application and further development of the ISC approach to other country contexts using in-depth data and test use of mass (police, insurance) datasets.
- Developing an ISC for vehicle-to-other road user interactions is vital to understand the full range of necessary interventions to address the full burden of road trauma.
- Full discussion of data, findings, limitations etc…are available in *Report* series.

Questions and Further Information



For reports on the Enhanced Crash Investigation Study (ECIS), go to: https://www.monash.edu/muarc/ecis or get in touch: Michael.Fitzharris@monash.edu