The MUARC-TAC Enhanced Crash Investigation Study: A platform to understand the causes and consequences of serious injury crashes

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Abstract

Background: In recognising the consequences of serious injury crashes, the Transport Accident Commission (TAC) commissioned Monash University Accident Research Centre (MUARC) to undertake the Enhanced Crash Investigation Study (ECIS). This paper describes the program components, seven key research questions and technical innovations used in the study. We describe the information collected and outline a 'Safe Systems Failure Analysis' used for each case.

Project Method: Participants in ECIS include drivers aged 18 years and older seriously injured in crashes on public Victorian roads. Drivers are recruited whilst inpatients at a major trauma hospital and where possible interviews conducted. The ECIS team inspects their crashed vehicle and critically analyses the crash environment. Event Data Recorder (EDR, black-box) data is acquired from vehicles where possible and crash reconstructions are undertaken. Each case is submitted to an internal panel review with a sub-sample of cases presented to external panels throughout Victoria. This process leads to each case being submitted to a Safe Systems Failure Analysis where contributing factors and countermeasures are identified by a broad group of stakeholders. The ECIS control arm permits examination of the relationship between certain factors, such as speed and crash occurrence.

Results and Discussion: In addition to describing the study, we provide an example of how the identification of crash factors, using a Safe Systems paradigm based on real-world serious injury crashes, can lead to the identification of targeted countermeasures, each with an identified policy action.

Implications: This paper will demonstrate a method for creating a robust evidence base upon which government road safety policy can be built. By scaling up individual crash findings to the broader crash population, countermeasures and associated policy actions can be appropriately prioritised.

Background

Despite impressive, and well-documented, sustained reductions in the number of people killed on Victorian roads over the past two decades, the same reductions have not been observed in the number of people injured. Casualty crashes and their associated costs continue to represent a significant financial and public health cost to the Victorian community. Costs incurred by the TAC, Victoria's no-fault statutory insurer, amounted to $AUD1.01 billion in the 2013/14 financial year (FY) in the provision of care, income support and other items to persons impacted by road trauma.

At a person level, the TAC supported 47,115 claims, of which 22,012 were new claims in the 2013/14 FY; this represents an increase of 13.7% on the previous financial year (Transport Accident Commission, 2014). In the 12-month period ending July 2014, a total of 6,018 Victorian road users were hospitalised (27% of new claims; 40% drivers, 15% passengers), with 900 of these admitted for a period of greater than 2 weeks (15% of those hospitalised; 44% drivers, 18%

passengers) (Transport Accident Commission, 2015). Notably, claims involving hospitalisation increased by 15%, while the number of claims (persons) requiring hospitalisation for greater than 2 weeks was stable (-1%) compared to the previous 12-months. Modelling undertaken by MUARC indicates that if left unchecked the number of people injured will increase simply based on population increases alone (ECIS Study Investigators, 2013).

While the economic cost of road trauma is high, those injured also experience considerable negative impacts on their personal life. Research demonstrates on-going impairments in everyday functioning, as well as a range of consequences including difficulties returning to work, relationship difficulties, on-going pain and mental health difficulties that can persist for extended periods of time following road trauma (Fitzharris, Bowman, & Ludlow, 2010; Fitzharris, Fildes, Charlton, & Kossmann, 2007).

Given the unacceptable nature of losses and harms associated with road trauma, the Victorian Government has committed to a Safe System approach in striving to achieve the vision of zero road deaths and zero serious injuries. As a pathway to realising this vision, a target of achieving a 30% reduction in both deaths and serious injuries was set in Victoria's Road Safety Strategy 2013-2022 (State Government of Victoria, 2013). Recent work undertaken by the Victorian Government under the *Towards Zero* consultative process further emphasises the commitment in striving toward achieving zero road trauma.

With considerable emphasis being placed historically on reducing the number of road deaths, shifting this emphasis to also reduce the number of people seriously injured requires a new approach to understanding the causes of these crashes. Consequently, the Victorian Government, through the TAC, funded the establishment of the *MUARC-TAC Enhanced Crash Investigation Study (ECIS).* The ECIS program was publicly launched in March 2014. The ECIS program aims to provide unprecedented insights into the causes and consequences of serious crashes, thereby supporting Victoria's efforts to implement the Safe System approach to road safety (OECD, 2008). It is expected that the comprehensive evidence generated through ECIS will help guide the Victorian Government's efforts to prevent crashes and reduce the cost of crash-related serious injuries.

This paper outlines the key elements of the ECIS program. In doing so, we describe the principal objective of the study and each component thereof. Further, we describe the conceptual approach adopted, program innovations, key questions, and demonstrate how the findings of the program will specifically inform Victoria's road safety policy and government road safety policy more generally.

The principal objective of the ECIS program is:

> *To determine the root causes of a representative sample of crashes and in 'scaling up' understand the determinants of high cost serious injury crashes.*

To meet this objective, the study will take a 'bottom-up' rather than top-down approach by 'scaling up' 400 serious injury crashes, the goal of which is to inform the Victorian Government on how to implement Safe Systems thinking to best prevent these occurring in the first place. The ECIS program consists of multiple components, each complementing one another, thereby providing further insights to the relative importance of crash and injury risk factors.

Methods

ECIS program components

The ECIS program consists of five integrated components, these being:

1. Establishment of a 'state-of-art' knowledge bank of serious injury crash risk factors and known prevention measures;

2. Comprehensive analysis of TAC Claims data linked with crash data;
3. In-depth investigation of serious injury crashes;
4. Conduct of a 'control arm', hence creating a 'case:control' study, and
5. Examination of five pedestrian serious injury crashes as a feasibility exercise.

A brief description of the components is described in turn.

Component 1 – Knowledge bank

This component will take the form of a series of literature reviews focussed on key behavioural, vehicle and infrastructure-based crash and injury severity risk factors. The purpose is to contextualise findings from the ECIS program as well as providing a usable knowledge bank of known countermeasures and their effectiveness. Dissemination will take the form of web-based fact sheets, peer reviewed journal papers and institutional reports based on a specific topic, such as the contribution of driver age and fatigue in crashes for instance.

Component 2 – Analysis of TAC Claims data

The TAC holds comprehensive information on each client making a claim following involvement in a road crash, including crash details, injury details using ICD codes obtained from hospital records (WHO, 2005), health and ancillary services used, and costs associated with medical expenses and an array of other costs including, for example, lifetime care costs determined by actuaries. The TAC has linked this data to the Victoria Police crash reports and the VicRoads Road Crash Information System (RCIS). MUARC has enhanced this dataset in a number of ways, including the derivation of a range of injury metrics, including the Injury Severity Score (ISS) and injury severity codes (AAAM, 2005; Baker, O'Neill, Haddon, & Long, 1974). A description of this dataset and explanation of crash costs can be found in Buckis, Lenné and Fitzharris (In press). This dataset provides a rich source of information on all crashes that have occurred on public roads in Victoria since 2000.

A detailed analysis of this data will be undertaken as a means of documenting specific crash characteristics with detailed cost of injury data. In addition, the dataset will be used to establish 'sampling weights' that will be used in 'scaling up' the sample of 400 crash-involved drivers described in Component 3 (below). In this way, we will be able to describe in numeric and financial terms, the magnitude of various crash risk factors, such as speeding and forms of inattention.

Component 3 – In-depth investigation of serious injury crashes

The central component of the ECIS program is the in-depth investigation of 400 crashes, based on the recruitment of 400 drivers aged 18 years and older admitted to hospital following injuries sustained in a road crash. At present, the study is being conducted at The Alfred hospital, one of two adult major trauma centres in the State of Victoria. There are no exclusion criteria based on crash location, thus enabling drivers involved in crashes from across Victoria to be eligible for the study. Drivers excluded are those who cannot provide informed consent due to mental health or social welfare considerations or medical grounds, given the advice of the treating staff.

Figure 1 provides a schematic representation of the different elements of Component 3. As shown, the key steps are 1) an interview with the injured driver whilst they are an in-patient in hospital; 2) a detailed inspection of the vehicle(s), and 3) a detailed investigation of the crash scene. Table 1 provides an overview of the information collected for each of the 400 cases.

Table 1: Overview of data collected, using a Safe Systems paradigm

Driver (via interview)	Vehicle	Environment
• Circumstances leading up to crash, including trip purpose,	• Full vehicle inspection for damage, cabin intrusion,	• Comprehensive scene inspection, including

length, familiarity with route • Crash events and vehicle details, including seat belt use. • Pre-crash behaviours, including inattention. • Use of medications pre-crash & pre-existing health. • Drug and alcohol questions. • Sleep patterns. • Contributing factors, including passengers, other road users, infrastructure, vehicle failure. • Driving and crash history. • Validated psychological scales	roadworthiness, crashworthiness. • Damage profile measured, and measures of crash severity (km/h) determined per SAE standard with *Ai Damage* for crash severity. • Event Data Recorder (EDR): pre-crash speed, braking, accelerator position • Crash type coding.	measurement of road, skid marks, signage, speed zone, road surface, presence and construction of shoulder. • Classification of road based on VicRoads network. • Use of VicRoads *CrashStats* to establish site crash history.

Table 2: Supplementary data sources

Supplementary data sources • Ambulance Victoria report, including transport times, treatment and conscious state using GCS; • Hospital medical records, including all injuries and treatment; coded using the AIS / ISS system; • Victoria Police crash report; • Photos from media coverage of crashes, and • VicRoads traffic count data for crash locations.

In cases where a driver is very severely injured, a relative / next-of-kin may be approached for purposes of informed consent and recruitment of the driver into the study. In these instances, no driver interview is undertaken. However, these cases remain extremely important given the severity of the crash and the resulting injuries. It is worth noting that a considerable amount of information can be gathered from the vehicle and scene inspection, as well as the supplementary data sources.

This component of the ECIS program follows broadly the processes adopted under previous in-depth crash investigation studies undertaken at MUARC. However, there are a number of innovations that distinguish ECIS from the earlier studies, including the technology used in crash reconstruction (i.e., HVE reconstruction software) and the inclusion of data from Event Data Recorders (EDR). These technologies, when used with in-depth data enable individual crashes to be reconstructed to estimate pre-crash speed and investigate the performance of the vehicle under a range of alternative scenarios, such as varied braking, reaction time and travel speed scenarios. It can, therefore, be systematically determined under what conditions that crashes may have been avoided or impact speed mitigated. An early example of this work is provided by Peiris et al. using ECIS cases where the effect of an earlier braking reaction time, improved road surface friction, and 'Wipe Off 5' (i.e., travelling 5km/h less) on crash outcome was examined (Peiris, Arundell, Gabler, Curry, & Fitzharris, 2015).

Of particular interest to the ECIS program is the influence of behavioural factors in crash causation. To this end, data collected includes a vast array of behavioural items. In addition to the open-ended and multiple choice items in the interview (see Table 1), the interview includes a number of validated health and psychological behaviour measures, including measures of general health and well-being (i.e., the SF-36), alcohol use (i.e., the World Health Organisation AUDIT), psychological health and distress (i.e., the Kessler K-10), driving behaviours using the Driver

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Behaviour Questionnaire (DBQ), and a collection of three measures of 'sensation seeking', 'reward seeking' and 'impulsivity' (i.e., Zuckerman's 'Impulsive Sensation Seeking Scale; Barratt Impulsiveness Scale).
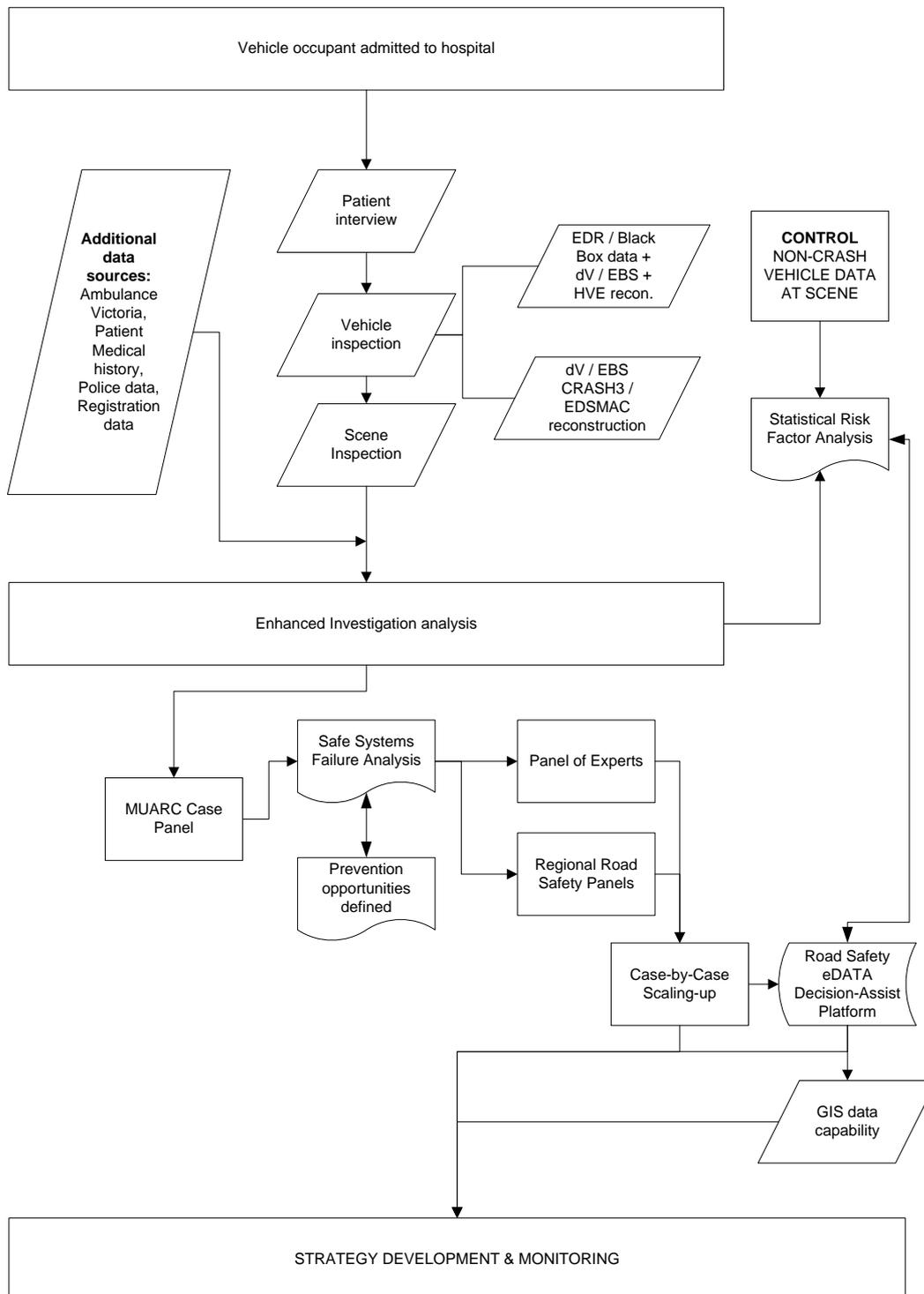

Figure 1: Representation of the MUARC-TAC Enhanced Crash Investigation Study

Analysis, use and interpretation of crashes – conceptual approach

The collected data for each of the 400 crashes are systematically analysed using an approach termed, *Safe Systems Failure Analysis*. The intent is to understand which elements of the 'system' aligned, or failed, such that the crash occurred. This is embedded in the principle of the Safe Systems philosophy whereby the key is to 'identify and rectify the major sources of error or design weakness that contribute to fatal and severe injury crashes, as well as to mitigate the severity and consequences of injury' (Peden et al., 2004: p.13).

For each crash, a *Safe Systems Failure Analysis* is undertaken within the project team, as well as when cases are presented at external expert panels. Throughout the process, contributing factors and evidence-based road safety policy options relevant for the whole network are identified. Each crash is individually examined with the Haddon matrix being used as the basis for the 'systems failure' analysis (Haddon Jr., 1968, 1972).

In examining each crash, key questions include:

1. What factors led to the crash?

2. What parts of the 'system' failed?

3. What parts of the 'system' were benign?

4. Was the crash potentially avoidable, the death preventable, or injuries able to be mitigated?

5. What factors are modifiable?

6. What can specific geographical regions learn from individual crashes that occur within their boundaries?

7. Scaling up, what policy options exist for the TAC and other road safety stakeholders in Victoria, based on the accumulated evidence, and known 'best practice' prevention, to prevent future 'like' crashes in Victoria?

In addition to the above, a '*Contributing Factors'* form developed specifically for use in the project is used by the MUARC ECIS study team to document all potential human, vehicle and environmental crash risk factors. Using this form, the investigation team note the occurrence or otherwise of each potential risk factor, and assign a confidence level, ranging from low, medium to high, that the factor contributed to the crash occurring or the severity of injuries sustained. The investigating team members (i.e., the Research Nurse and the Vehicle / Scene inspector) complete this form individually and are required to note the evidence source for each factor. This form is then reviewed by the broader ECIS team as part of an internal case review.

In total, included in the conduct of ECIS over a 3-year period are 12 city-based Expert Panels and 6 Regional Expert Panels. During these panels, cases are presented to a variety of experts from government, including police, road agencies, road safety bodies, ambulance and medical personnel, and local government officers. The principle objective is to gain further insights into countermeasure options from practitioners as well gain an increased understanding of the range of considerations impacting the implementation of road safety policy. The panels have a secondary benefit of highlighting the Safe Systems approach of road safety to a wide variety of Victorian stakeholders.

Recruitment response rates and sample characteristics: At the time of writing (end-August 2015), 146 drivers had been recruited into the study, representing 144 serious injury crashes, noting that both drivers from two separate crashes were enrolled in the study. Informed consent was obtained for each injured driver, with a relative / next-of-kin providing informed consent on behalf of six severely injured drivers.

Since recruitment commenced (11 August 2014), a total of 1,100 persons injured in road crashes were admitted to The Alfred hospital and screened for participation; of these 498 (45.2%; 61%

male) were drivers of passenger vehicles. Following study protocols regarding inclusion and exclusion criteria, as well as operational matters (i.e., nurse availability), 223 injured drivers were approached with the view of seeking their participation, representing 45% of all injured drivers admitted to The Alfred hospital. Of the remainder who were not approached (55%, n=275), 154 (31%) met study exclusion criteria (e.g., driver aged less than 18 years, medical grounds, psychological distress post-crash), 114 (23%) were discharged prior to being approached and 7 died in hospital (1%).

Of the 223 injured drivers approached, 146 consented to participation (60% male), 71 declined (56% male) and 6 patients were discharged prior to consent being gained (50% male). Hence, the response rate of those approached was 65.4%, the refusal rate was 31.8% and the percent lost due to discharge after approach but consent not being immediately received was 2.6%. The 146 consenting drivers represents 29.3% (i.e., n=498) of all drivers admitted to The Alfred hospital in the study period.

Sample representativeness is an important consideration, particularly in the ability of the study to make inferences to the broader serious injury crash problem. This relates to issues of participation and response bias. To this end, the sex and age distribution of all drivers admitted to The Alfred, as well as those recruited to ECIS and those declining participation was examined (Figure 2). By way of example, it can be seen that of all the drivers admitted to The Alfred hospital, 7% were females aged 18-25 years and 13% were same-aged males. Of the 146 drivers who agreed to participate in the study, 7% were 18 to 25 year-old females and 12% were 18 to 25 year-old males; of those that declined (n=71), 4% were 18 to 25 year-old females and 15% were 18 to 25 year-old males. While there are some small differences in the ECIS sample compared to all drivers admitted, chi-square analysis comparing the age/sex profile of participants vs. refusals and participants vs. all other drivers indicates these differences were not statistically significant (p>0.05).
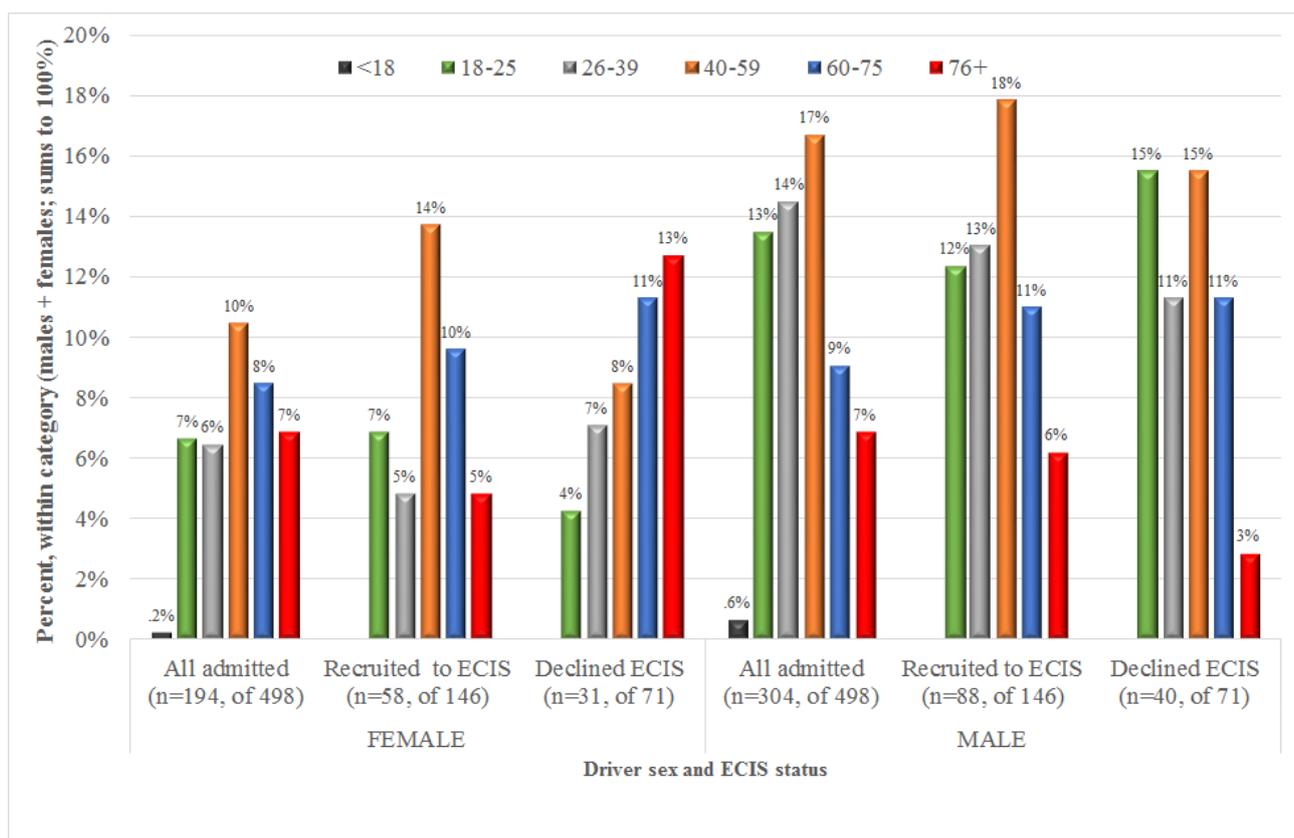

Figure 2: Sex and age profile of drivers admitted to The Alfred hospital, those recruited to ECIS and injured drivers declining participation

ECIS participant characteristics

Of the 146 drivers recruited to date, 19% were drivers aged 18-25 years (male: 64%), 17.8% were aged 26–39 (male 73%), 31% were aged 40–59 years (male: 56%), 20% were aged 60-75 years (male: 53%), and 11% were aged 76 years and older (56% male). The mean age of males was 45.6 years (*SD*=2.7; 95%CI: 40.1-51.1, Median: 43) and ranged from 18 – 86 years, while the mean age of females was 48.3 years (*SD*=3.2; 95%CI: 45.6-52.5, Median: 55) and ranged from 19 – 86 years of age.

Injury severity metrics - The mean length of stay did not differ across the five age groups shown in Figure 2 (mean: 9.3 days, 95%CI: 7.9-10.8; p>0.05) while the median was 7.5 days and 54% were hospitalised for 7 days or longer. Overall, half (52%) of the sample sustained a 'serious' (AIS3), 'severe' (AIS4) or 'critical' (AIS5) injury; this is referred to as an AIS3+ injury.

A higher proportion of drivers aged 18–25 years sustained an AIS3+ injury (70%), compared to all other age groups (26-39: 47%; 40-59: 38%; 60-75: 55%; 76+: 54%), although this difference was not statistically significant (p=0.3). Similarly, 70% of drivers aged 18-25 were classified as a 'major trauma' patient under the Victorian State Trauma Protocols (i.e., ISS >12), compared to between 42% and 55% of other age groups.

The higher severity of young driver crashes is seen in the mean Injury Severity Score (ISS) for the 18-25 year old group being 17.2 (SD=10.7, median: 15.5, range: 1-36) compared to the overall mean of the other age groups being 12.1 (SD=10.4, median: 9, range: 0-45) (p=0.053). Despite the injury severity among young drivers to be higher, the length of stay of 18-25 year old drivers (mean: 9.9 days, SD=8.8, median: 6.5, range 2-37) did not differ compared to drivers in all other age groups (mean: 9.2, SD=6.9, median: 8, range 1-27). Notably, fewer young drivers (40%) were discharged to a rehabilitation facility than older drivers (i.e., 60-75 years: 65%; 76+: 46%).

Vehicle age and crash type: The data also highlights a difference in the age of vehicles being driven at the time of the crash, with 75% of drivers aged 18-25 years driving a vehicle at least 10 years old, and half driving a vehicle more than 15 years old. In contrast, approximately 33% of drivers aged 60+ were driving vehicles aged 10 years or older, with one-third driving a vehicle of at least 10 years of age at the time of the crash; this difference was not however statistically significant. Only 5% of young drivers were driving a vehicle less than 3 years old. A higher proportion of young driver crashes were single vehicle crashes (SVC)(45%) compared to all other age groups, with the percent of SVC being 32% for 26-39 year old drivers, 31% for 40-59 year old drivers, 10% for 60-75 year old drivers and 15% for those over 76 years of age.

In short, based on the available data to date, young drivers – who represent 19% of those injured, are more likely to have been involved in single vehicle crashes, driving older vehicles, and were more severely injured than drivers aged 26 and older.

The data concerning sample demographics and injury severity are provided to give a general picture of the profile of drivers recruited to the study. While no robust conclusions can be drawn from this small sample, the differences in crash type and injury severity are notable, as is the similarity in the length of stay in hospital across age groups, despite differences in objective measures of injury severity. Future publications will focus on factors associated with crash risk, as well as further exploring the relationship between driver age, vehicle age, crash type and injury outcomes.

Consent to follow-up: Of significant interest is the pattern of recovery and health services used post-crash. To this end, 66% of the injured drivers have provided consent that enables future contact and follow-up to be made, 29% requested they not be contacted in the future, and 4% were next-of-kin consent cases where this is not appropriate. This data collection protocol is under development at the time of writing.

Ethics approvals

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The ECIS case arm has been approved by the Monash University Human Research Ethics Committee (CF14/2329 - 2014001254) and The Alfred Hospital Human Research Ethics Committee (Approval: 249/14). These approvals dictate that individual case information be de-identified of all identifying details within four weeks of case recruitment, and that no identifying information be divulged to any party, organisation or person outside of the ECIS study team.

Component 4 - The 'control' arm (drivers not-involved in crashes)

The 'control' arm of the study aims to establish the profile of drivers that successfully pass through a crash (case) location; this is referred to as the 'study location'. The conduct of this component adds a 'case-control' element to the ECIS program. This permits estimates of risk to be determined for various factors, including for instance, vehicle speed, inattention, fatigue, and weather conditions. This is similar to studies previously conducted by Kloeden et al. who documented the crash risk associated with free travelling speed in urban and rural Adelaide (Kloeden, McLean, Moore, & Ponte, 1997a, 1997b; Kloeden, Ponte, & McLean, 2001). The ECIS study aims, however, to examine risk factors in addition to vehicle speed, alone, and in combination with one another.

Method: A control 'site' is that where an ECIS crash 'case' occurred (refer Component 3). In the one or two weeks following the crash, logistics permitting, a MUARC Technical Officer attends the crash site and using a LaserCam 4 (Kustom Signals, USA) covertly records the free speed of vehicles successfully passing through the crash site without experiencing a crash. Data is recorded for 30 minutes either side of the known crash time. Matching is undertaken only on day of week, time of day, and if possible, road conditions (i.e., wet / dry). For single vehicle crashes, only vehicles travelling in the direction of the 'case vehicle' are recorded, while for multiple-vehicle crashes (i.e., on-coming, intersection) vehicles from both directions are captured. Data captured includes vehicle speed, time of day, weather conditions, road conditions, vehicle manufacturer and model and vehicle registration. Traffic density is also collected, as well as details of all vehicles passing through the study location. As a way of providing a point of differentiation for drivers who pass through the location routinely, a large metal yellow sign is placed *after* the point of vehicle speed being recorded, stating *"You have passed through a Monash University study location".* A survey item (see below) specifically asks whether the driver has seen the sign.

Sampling and statistical power: Using the data collected, a paper-based survey is sent to 12 drivers travelling in each direction (if appropriate). Initially, surveys were sent to 30 drivers (in each direction) for the first 25 control cases; this was done to establish a representative response rate. Following this, the number of surveys sent was reduced to 12 based on an observed response rate of 25% and the recommendations for a 3:1 control:case ratio (Rothman & Greenland, 1998).

Survey procedure: Having captured vehicle details, the MUARC ECIS team then send to the TAC a pre-prepared survey pack, each with a unique code. This code is used by MUARC to link survey responses to the observed travel speed. MUARC supplies the TAC only with the vehicle registration number, who then sends the survey to the registered vehicle owner. The process is designed such that the registered owner receives the survey within 4-5 days of being recorded passing through the study site. The registered vehicle owner is provided a plain language statement and consent form while the survey provides a photo of the road where their vehicle was seen, ideally with no vehicle in view. The registered owner is asked to pass the survey to the driver of the vehicle at the stated day, time and location. A store voucher to the value of $50 is provided to drivers that return the survey within 2-weeks. The survey takes approximately 60–90 minutes to complete.

Survey materials: The 'control' survey is purposefully aligned with the 'case' questionnaire, minus questions relating to crash involvement. The survey contains items specific to driving through the

location when observed, as well as questions relating to driving behaviour, speed choice, driving, crash and offence history, a detailed health profile, plus the validated survey instruments.

Early response rates: At the time of writing (end-August 2015), 60 'control' sites had been studied, with surveys sent to 1,785 drivers. Of these, 572 completed surveys have been received representing a response rate of 33%. A small percent of surveys (3%, n=52) were not sent by the TAC or were returned due to incorrect contact details; in such cases the registered owner had changed residence but had yet to update their address details in the licensing and registration system. Future work will provide an online option for completion of the survey and an assessment of the representativeness of survey respondents will be made.

Ethics approval

The ECIS control arm has been approved by the Monash University Human Research Ethics Committee (Control Arm CF14/1930 – 2014000983). This approval dictates the research comply with all relevant legislation concerning privacy, that survey responses be de-identified within 2 weeks of receipt by the ECIS team, and no identifying information be divulged to any party, organisation or person outside of the ECIS study team.

Component 5 – In-depth investigation of pedestrian crashes

This component seeks to examine five serious injury pedestrian crashes with a view to optimising future research opportunities and the expansion of the ECIS program into vulnerable road user groups. This component will involve the use of multiple data systems, including co-operation with Victoria Police amongst others. This component is presently under development but will involve similar methods and supplementary data used in Component 3.

Results - Early Insights

A key driver for the establishment of the ECIS program is to develop a comprehensive understanding of the full range of factors associated with serious injury crashes. This is done using a Safe Systems approach with a view of identifying a broad range of relevant and specific countermeasures and suitable policy actions for each crash. The establishment and conduct of city-based expert panels and regional expert panels is aimed at gaining insight from a range of different perspectives. To date, five city-based expert panels and two regional expert panels have been held; these involved the participation of 141 and 71 experts, practitioners and road safety stakeholders respectively, including visitors from Sweden and Africa. Panel participants represented local government, hospital-based medical staff, and all road safety agencies in Victoria. During these panels, a total of 21 ECIS crash cases have been presented, and for a select number vehicle speed data as measured through the control arm of the program was also presented. In reviewing these cases, the Expert Panels have made a number of high-level observations and have identified opportunities to implement innovative actions with the goal of reducing the number and severity of crashes, including the need to:

1. Manage vehicle speed where road and roadside infrastructure has not been designed to accommodate human error, that is, where infrastructure safety is of lower quality than the current speed limit might permit under a Safe Systems paradigm;
2. Build licensing, monitoring and infringement systems to monitor fitness to drive;
3. Examine innovative ways to control impaired driving;
4. Create and build systems and road infrastructure to manage non-compliant behaviour;
5. Create and build road infrastructure to accommodate a diverse range of human factors and errors, and
6. Mandate new vehicle safety standards and incentivise safe car selection.

These observations and recommendations have stemmed from the identification of factors associated with the crashes reviewed. Following the establishment of contributing factors, countermeasure options for each are identified and discussed, with each of these being translated into potential policy actions. As an example, Table 3 presents crash factors, countermeasures and policy actions that fall under the category of building a licensing, monitoring and infringement system that incorporates fitness to drive measures (see point 2 above). Further work is being undertaken to determine implementation issues and the likely effectiveness of these countermeasures and associated actions. This information is however presented here as an example of the approach being adopted in the ECIS program and the insights that can be gained. This process has been used in analysing each crash with the higher level categories noted above as 1-6 being established thus far, however these are not presented here due to space considerations.

Table 3: Crash factors, countermeasures and potential policy actions based on fitness-to-drive considerations seen in the reviewed ECIS cases

Contributing factor to crash	*Countermeasure*	*Potential policy action*

• Alcohol
• Drugs
• Abuse of prescription medications, alone and in combination with alcohol
• Emotional Stress
• Fatigue
• Human error
	• Alcohol interlocks
	• Drug interlocks
	• GP/Pharmacist advice on use on medication
	• Directly target drivers misusing prescription medication
	• Educate public on risks associated with:
	   o Impairing effects of alcohol
	   o Impairing effects of medications (& combinations)
	   o Fatigue / drowsy driving
	   o Emotional stress and driving
		• Mandatory alcohol interlocks, possibly using an incremental phase-in approach
		• Stimulate the development of drug interlock technologies
		• Link GP / Pharmacy / licensing databases to identify and contact high-risk drivers with a view to increasing their knowledge of impairment of certain medications.
		• Develop Fitness to Drive measures that determine when licensing should be reviewed and restricted based on risk profile
		• Raise public awareness of role of both mental health and fatigue on road safety

Discussion

This paper outlines the establishment of a comprehensive multi-component crash investigation system in Victoria, the goal of which is to provide the necessary understanding of the causes and consequences of serious injury crashes. The impetus for the establishment of the ECIS program was recognition that serious injury crashes carry considerable social, personal and financial cost to those involved as well as society more broadly. Given the TAC's role in providing care for those injured, including lifetime support, in addition to having a statutory responsibility for the prevention of road crashes, there is considerable investment in the ECIS program by the TAC.

The value of the ECIS program to the TAC and to the Victorian Road Safety Stakeholders will be in the insights it provides as to the underlying causes of serious injury crashes. More than that though, the ECIS program aims to offer definitive countermeasure solutions linked to cost-effective road safety policy. This program will provide the necessary evidence-base required for the establishment of innovative and perhaps challenging road safety strategies and action programs, an example of which can be seen in the direct links drawn between factors associated with real-world serious injury crashes, countermeasures and potential policy actions with respect to fitness-to-drive measures presented here. In using the Safe Systems approach, the full range of crash factors can be examined with highly specific and tailored countermeasures and innovative policy actions being identified.

The strength of the ECIS program is its multi-component nature, each of which provides a different but complementary insight into incidence, scale, underlying causes and outcomes of crashes. By adopting the latest innovations in data collection methods, and best practice science, the study will be well placed to deliver on its objectives. Despite the 400 crashes representing approximately 15% of all drivers admitted to hospital across Victoria, it is considered that the insights gained will be significant. It is also not considered feasible, practical or necessary to collect this type and amount of data on 100% of serious injury crashes; hence, a sampling approach supplemented by analysis of population-based road crash and claims data represents in our view, the most efficient way forward. Early analysis indicates that the ECIS sample is representative of the broader demographic of drivers involved in serious injury crashes, which is important in the context of 'scaling up' our insights to the broader crash problem.

A further strength is that the entire ECIS program is rooted firmly in the Safe Systems paradigm, a paradigm that underpins the new Victorian Road Safety Strategy, known as 'Towards Zero'. Indeed, the ECIS program covers the five road safety pillars enunciated in the *United Nations Global Plan for the Decade of Action for Road Safety 2011 – 2020*, these being:

1. Road Safety Management: target setting, data system establishment for defining, monitoring and evaluating road safety countermeasures;
2. Safer roads and mobility: to raise the inherent safety and protective quality of road networks for the benefit of all road users;
3. Safer vehicles: encourage universal deployment of improved vehicle safety technologies for passive and active safety through a combination of harmonisation of relevant global standards, consumer information and incentives to accelerate the uptake of new technologies;
4. Safer road users: develop comprehensive programs to improve road user behaviour focussed on key risk factors, and
5. Post-crash response: increase responsiveness to post-crash emergencies and improve the ability of the health and other systems to provide appropriate emergency treatment and longer-term rehabilitation for crash victims.

By design, the ECIS program engages with experts in each of these pillars, as evidenced by the Australian and International project team, and the composition of external panels. Further, the expert and regional panels offer an additional forum to seek the input of a wide variety of experts who provide invaluable insights into road crashes from a range of diverse backgrounds. A core output of the Panels is the formulation of an outcome document that lists contributing factors, countermeasure opportunities and their policy implications as seen here. The inclusion of the medical, legal and regulatory community is an important aspect of the study.

In addition to the contribution to future road safety programs, the ECIS program can play a broader educative role in the community. Through various channels, the findings of the ECIS program will be actively disseminated. This will be done with a view to align community attitudes on the

importance of preventing serious injury road crashes with the importance of preventing fatal crashes.

Finally, the ECIS program will collect thousands of variables on each crash it investigates as well as on drivers passing successfully through locations where crashes have recently occurred. This method will provide new insights into a wide range of crash risk factors that have historically been difficult to quantify, such as distraction, fatigue and low level speeding. By examining each crash according to the developed 'Safe Systems Failure Analysis' paradigm, the ECIS team will be in a position to identify prevention opportunities in each element of the road transport system. The integration of findings from all of the study components will enable a complete picture of serious injury crashes to be achieved. From this, opportunities to prevent future crashes will be identified.

Limitations

The ECIS study acknowledges a number of limitations. The study is focussed on drivers of passenger vehicles, who are seen to account for 40% of all road users admitted to hospital, with passengers comprising an additional 15%. Hence, this study does not directly capture a large proportion of the serious injury crash problem, however, the insights gained may have application to other collision types that involve driver-to-pedestrian, driver-to-cyclist and driver-to-motorcyclist crashes. Given that the study aims to interview drivers injured in crashes, there may be instances where a passenger is injured but the driver is not; the extent of this and implications will be considered and documented as the ECIS study proceeds. There is also a need to examine crashes involving trucks, from the perspective of the truck driver, and indeed, a number of ECIS drivers were injured following collision with trucks. Expansion of the inclusion criteria to other road user groups is being examined, and this is important as the contributing factors, countermeasures and policy actions will likely differ depending on crash configuration and road users involved. The study also excludes drivers less than 18 years of age, principally for reasons of the practicality of gaining informed consent and also as they represent a small proportion of admitted patients as drivers (0.2%), as shown in Figure 2.

For multiple vehicle crashes, only one of the drivers is usually interviewed and their vehicle inspected. The one exception to this can be in the uncommon event of both drivers being i) injured, and ii) admitted to the recruiting hospital. For the two instances of 'driver pairs' being consented to the study, the Research Nurse team were unaware that both drivers were in the same crash until case processing commenced. While there would be added value in being able to interview both drivers involved in all recruited cases, assuming the other driver was not deceased, and conduct an inspection of both vehicles, this is not feasible for a number of reasons. Assuming the other driver is admitted to a hospital other than the current recruiting hospital, the ECIS study team would have to seek this information, as well as personal and health information, from a government agency, without that persons consent to do so. In such cases, the government agency would first have to contact that driver to seek permission to release details to the ECIS team. If it were possible to obtain this information and in the instance the other driver was admitted to hospital, the ECIS study would then require ethics approval in almost every hospital in the State so that there can be an assurance that the driver can be approached whilst in hospital; this is impractical for the purposes of the study due to time and resource limitations. It could also be expected that the response rate following this approach would be low, and it is probable that there may be bias in those drivers consenting for their details to be released to the ECIS team.

Following from above, the time to identify, contact, and consent the 'other' driver would be considerable–whether admitted to hospital or not–by which time it would be anticipated that memory of the crash event may have degraded, particularly given the nature of interview questions, and their vehicle likely repaired or destroyed. Further, depending on the extent of injuries sustained, and the capacity of the driver to consent, it may not be appropriate to seek contact with them

directly, which would lead to contact with the next-of-kin; both of these have implications for ethics and privacy laws and release of personal information to the researchers. It is also considered that contact by telephone or letter be inappropriate due to potential for distress and harm, and ECIS protocols ensure that nursing and medical opinion is sought prior to approaching an injured driver.

While not directly seeking to interview both drivers of multiple vehicle crashes for the reasons noted above, it is considered that the protocols adopted by the ECIS study provide a robust basis for understanding the crash events and the role of both drivers with respect to pre-crash behaviours and any illegal driving behaviour on the part of both drivers involved.

Within both the 'case' and 'control' arm, sample representativeness and response bias are key considerations. As indicated, 65% of eligible injured drivers approached elected to participate in the study, and the age-sex profile of the ECIS driver sample is well matched to the broader injured sample, of which the ECIS drivers represent 29%. However, it is acknowledged that within each age-sex group, the reasons for declining participation might differ – including engaging in illegal behaviours such, for example, drink-driving, and this aspect needs to be monitored and reported upon. To date though, the sample includes drivers affected by alcohol and illicit drugs, as well as those who stated that they fell asleep whilst driving. Further work will examine this issue of potential bias and the impact on study findings. Sample representativeness of the case drivers will also be examined by reference to the analysis of the TAC Claims profile, which will include driver age and sex, crash type (i.e., single / multiple vehicle crash; crash type using the VicRoads Definition for Classifying Accident Code [DCA]; speed zone), impact object and, injury severity (i.e. length of stay, AIS severity) (see Component 2). Using these parameters, sampling weights derived from the analysis of the TAC Claims data will be used to 'scale up or scale down' cases so that they are collectively representative of the total serious injury crash problem in Victoria. A sampling procedure previously developed by Fitzharris et al. will be utilised here (Fitzharris, Scully, Fildes, & Gabler, 2005). This step will ensure insights gained from the ECIS serious injury cases will be appropriately weighted to reflect all serious injury crashes in Victoria.

Similarly, the response rate for the control arm has been shown to be 33%. Data is being collected on all vehicles that pass through the study site so that an assessment can be made of response bias based on vehicle speed and vehicle type and driver characteristics based on observation. Any bias is likely to impact on crash risk estimates calculated, and hence, this issue is being examined in detail.

A further limitation relevant to the 'case' arm is the inability, on a small number of occasions, to inspect the vehicle involved in the crash. This can occur in instances where the injured driver is not being the registered owner of the vehicle and the registered owner does not provide consent for the ECIS team to examine the vehicle, or the vehicle being sold and / or crush prior to the inspection being undertaken.

The ECIS study is not designed as an 'on-the-spot' study, with data collected retrospectively. The limitation of this is that the data at the scene of the crash may have degraded, however every effort is made to attend the crash scene within days of driver consent being granted. The use of multiple information sources, including photos obtained of the crash through media and other reporting mechanisms significantly enhances the understanding of the crash, and can overcome the deficiencies characteristic of retrospective crash investigation studies.

Finally, in the reconstruction of cases the simulation software (i.e., AI Damage, HVE) has a number of limitations relating to vehicle stiffness, which may influence estimates of crash severity and pre-crash speed, although a confidence range is also given. The study also aims to utilise EDR data, however not all vehicles in the study sample have these fitted, and not all can be downloaded at present due to proprietary technology reasons, thus limiting the number of cases for which objective recorded pre-crash driver behaviour is available.

Conclusion

This paper outlines the establishment and components of a comprehensive system for understanding the causes and consequences of a representative sample of serious injury crashes. Selected early insights have been presented. Using the *Safe System* as a conceptual basis for understanding the contributing factors for 400 serious injury crashes, and supported by a 'control arm', it is expected that the ECIS program will provide a new understanding of crash risk factors. As part of this process, a stated objective is to identify countermeasures and the associated policy implications for each observed risk factor. With the high number of serious injury crashes it is not feasible to study each in sufficient detail to conduct a comprehensive Safe Systems analysis. However, the use of sampling weights and an analysis of 10-years of TAC Claims data linked to crash data, the study will provide a strong platform for better understanding the determinants and relative importance of specific risk factors associated with serious injury crashes. In turn, this will permit an understanding of how reductions in high cost serious injury crashes to the TAC can be achieved. This understanding will further assist the TAC and those in the Victorian Road Safety Partnership (i.e., VicRoads, Department of Justice, Victoria Police, Department of Health and Human Services) to make highly targeted, and cost effective, decisions on how to best to prevent and mitigate serious injury crashes relevant to the whole State of Victoria. Collectively, the insights gained from all elements of the ECIS program will provide policy-makers the necessary tools to deliver a safer road transport system in Victoria.

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ECIS Study team

In addition to those named in the author by-line, the ECIS team consists of: Research Nurses: Sarah Bullen, Marnie Reilly, Emily Robertson, Karen Vlok; Technical Officers: Rai Curry, Robin Jackel, Lindsay Lorrain, Tandy Pok Arundell, Geoff Rayner; Data Coordinator: Debra Judd; Project Support Officer: Caitlin Bishop, Hayley McDonald.

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