

# The relative contribution of system failures and extreme behaviour in South Australian crashes: Preliminary findings

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## Abstract

Within the road system, there are compliant road users who may make an error that leads to a crash, resulting in a 'system failure', and there are also road users who deliberately take risks and display dangerous or 'extreme' behaviours that lead to a crash. Crashes resulting from system failures can be addressed through improvements to road system design more readily than crashes resulting from extreme behaviours. Therefore, the classification of crash causation in terms of system failures or extreme behaviour is important for determining the extent to which improvements to the road system can be expected to reduce the number of crashes. This study examined the relative contribution of system failures and extreme behaviour in South Australian crashes as identified from information in Coroner's investigation files and databases of in-depth crash investigations conducted by CASR. The analysis of 83 fatal crashes, 272 non-fatal metropolitan injury crashes and 181 non-fatal rural crashes indicated that very few non-fatal crashes (3% metropolitan, 9% rural) involved extreme behaviour by road users and, even in fatal crashes, the majority (57%) were the result of system failures. This means that improvements to the road transport system can be expected to be much more effective in reducing crashes than concentrating on preventing extreme behaviours. Such a strategy could reduce the incidence and severity of a large proportion of crashes in South Australia.

**Key words:** Fatal crash, Accident investigation, Road user behaviour, Coroner, Safe system

## 1. Introduction

Traditionally road safety has focused on the relative contribution of the driver, the vehicle and the road in crash causation. In Australia, there has been a recent paradigm shift to a Safe System approach that recognises the interaction between wider systemic failures and individual operators (i.e. road users). Based on the Swedish 'Vision Zero' (Tingvall, 1997) and the Dutch 'Sustainable Safety' (Wegman & Aarts, 2006) approaches, the Safe System approach has been adopted in Australia as a guiding framework for delivering road safety policy and forms the basis of the new Australian National Road Safety Strategy (Australian Transport Council, 2011). A diagram of this framework can be found in the OECD (2008, p.114) report "Towards zero: ambitious road safety targets and the Safe System approach".

The Safe System approach recognises that road users are fallible and will make errors, and that system design should take into account the force that a human body can tolerate before injury occurs. A key part of the approach is designing infrastructure that takes account of human errors and minimises impact forces when collisions occur so that people are able to avoid serious injuries or death when using the road system. This represents a fundamental shift away from an approach placing almost sole responsibility for safety on the road user, to an approach that compels system designers to provide an intrinsically safe environment (OECD, 2008).

To be effective the Safe System requires 'alert and compliant' individuals using the road network. Such responsible road user behaviour can be promoted through the prudent management of the entry and exit of vehicles and users to the system, by providing supportive education and information to road users, by the enforcement of road rules, and

through a better understanding of road crashes and risks. Nevertheless, the system must still be forgiving of those who use the road responsibly but who make mistakes.

There are compliant road users who may make an error while using the road system. If this error results in a crash, it might be considered a 'system failure'. There are also road users who deliberately take risks and display dangerous or 'extreme' behaviours that lead to crashes. For example, alcohol use and speeding behaviour are associated with exponential increases in the risk of crashing (Borkenstein *et al.*, 1964; Kloeden *et al.*, 1997).

It is currently not known what proportion of crashes in Australia can be attributed to extreme behaviours and what proportion are due to road users making simple errors within the road system resulting in 'system failures'. Previous research in this area has concentrated on estimating the contribution of individual driver errors rather than system wide failures (for a review of human error models see Salmon *et al.*, 2010).

Understanding the relative contribution of system failures and extreme behaviours in crash causation has important implications for the improvement of road safety in Australia. According to the Safe System approach, crashes resulting from system failures can be addressed through improvements to the road system, specifically management of infrastructure, travel speeds and vehicle design. The identification of these crashes and their characteristics can inform future system design. As there is a limit to the extent to which infrastructure and vehicle design can accommodate crashes resulting from extreme road user behaviour (Turner *et al.*, 2010), such behaviour might require different types of countermeasures.

To obtain a better understanding of the relative contribution of system failures and extreme behaviours in crash causation, two sources of detailed crash information are used in this study.

The first of these is the information contained in Coroner's files pertaining to fatal crashes in South Australia. Fatal crash investigations provide a comprehensive and systematic examination of the factors involved in crashes. Deaths resulting from road crashes in South Australia are legally required to be reported to the state Coroner for investigation. Through the routine investigation, the state Coroner obtains detailed information about the circumstances surrounding a fatal crash.

The other source of detailed crash information used in this study is the in-depth crash investigation database maintained by the Centre for Automotive Safety Research (CASR). CASR investigates road crashes in-depth, including immediate attendance at the scene of the crash. The CASR in-depth database includes cases ranging in injury severity from minor to fatal. As the Coroner's files provide detailed information pertaining to fatal crashes, it was decided that the main value that could be added to the study by the use of CASR in-depth crash data was the analysis of non-fatal crashes. This enables a comparison between fatal and non-fatal crashes in terms of the relative importance of extreme behaviour or system failures.

## **2. Method**

To examine the relative contribution of system failures and extreme behaviour in South Australian crashes, two datasets were used: Coroner's files and CASR in-depth crash investigations.

### **2.1. Coroner's files**

Deaths resulting from road crashes in South Australia are legally required to be reported to the state Coroner for investigation, as stated in the *South Australia Coroner's Act 2003*. State Coroner files are an important source of detailed information for fatal road crashes. While the National Coroners Information System (NCIS) provides a good source of information for crash event classification, the data contained in the original case files provides much more

detailed information for investigating the failures of different aspects of the safe system (see Young & Grzebieta, 2008).

The Coroner's files contain a diverse range of information on a specific fatal crash. Files typically include a report compiled by the investigating police officer (i.e. Major Crash investigator), a forensic autopsy report, a forensic toxicology report, and a brief summary of the Coroner's findings relating to the cause of death. The police report generally includes photographs and a map of the scene, interviews with surviving participants and witnesses, a mechanical inspection report for all vehicles involved in the crash, details of any charges against individuals involved in the crash and any other relevant information. While each file generally contains the aforementioned information, the extent and quality of the information varies from case to case.

This study examined motor vehicle crashes resulting in at least one fatality during the 2008 calendar year in the state of South Australia. The term 'fatal motor vehicle crash' refers to any event reported to the police or authorities resulting in death that was attributable to the movement of a road vehicle on a road. This definition extends to include crashes involving a road vehicle (including motorcycles) and a pedestrian or bicycle. Cases were excluded if they did not occur on a public road or road related area, if the crash was intentional (i.e. suicide attempt) or if the fatality resulted from natural causes (i.e. to be included, the fatality had to be the result of injuries sustained during the crash, not the result of a pre-existing condition such as a myocardial infarction or cerebrovascular disease). Also, all Coroner's files included in the study were completed or 'closed' files. This restriction resulted in the omission of seven 'open' cases from the data set.

For the calendar year 2008, 90 'closed cases' or fatal crashes (100 fatalities) involving a motor vehicle and occurring in South Australia were identified by the Coroner's Court. Of these, seven crashes did not meet the study inclusion criteria. Three crashes were identified as intentional (i.e. successful suicide attempts); one crash occurred during an official car racing event; two deaths were due to natural causes associated with heart disease (primary causes of death: myocardial ischaemia, aortic arch aneurysm); and one death was the result of a fall from a parked heavy vehicle that was not on the road at the time of the event. As a result, a final sample of 83 fatal crashes, resulting in 93 fatalities, was included in the study.

In this sample of fatal crashes 13% (n=11) involved a vehicle colliding with a pedestrian, 51% (n=42) involved a single vehicle, 36% (n=30) were the result of a multiple vehicle collision of which half occurred at intersections and half were midblock. Around 41% of fatal crashes occurred in metropolitan areas, 48% in regional areas and 11% in remote areas.

The research design was primarily descriptive and explorative, and involved the examination of road crashes resulting in fatal injuries for a full 12-month period to determine the proportion of crashes attributable to system failures and extreme behaviour. Two road safety experts with over twelve years of crash investigation experience independently reviewed and analysed each Coroner's investigation file for fatal crashes that met the inclusion criteria. As a secondary check, both investigators reviewed all cases together to ensure concordance.

A database was designed to record information for each fatal crash and the people and vehicles involved in each crash. The variables recorded for each crash were either categorical or descriptive and included the following information:

- Nature of the crash (brief description of the crash, day and time of the crash, location of the crash, number of vehicles involved, crash type, main type of impact).
- Cause of death and nature of injuries (post mortem findings).
- Driver, rider, cyclist or pedestrian factors (age, sex, forensic toxicology results, seat belt compliance, licence status, any errors identified by police, charges relating to the crash, seating position in vehicle, frequency of use of road, frequency of use of

vehicle, trip purpose, indigenous status, motorcyclists: protective clothing, conspicuity and helmet use).

- Vehicle factors (make, model, age of vehicle, number of vehicle occupants, vehicle identification number (VIN), condition of vehicle, travelling speed, headlight use, air conditioner setting, vehicle safety features: electronic stability control (ESC), airbags including deployment status).
- Road and environmental factors (weather conditions, lighting conditions, speed limit, class of road, road layout, road surface, road alignment, road delineation, intersection controls).

## 2.2. CASR in-depth crash investigation

CASR has been conducting at-scene in-depth crash investigation for many years. CASR crash investigation teams are made up of engineers, psychologists and health professionals who travel to the crash scene immediately after being notified about the event on the ambulance radio or ambulance pager. Information collected at the scene includes details of the crash-involved vehicles, and all aspects of the road and road environment potentially relevant to the crash, including crash specific information such as braking marks and impact points. Follow-up work includes collection of documents relevant to the crash (e.g. police reports, Coroner's reports for fatal crashes), collection of injury and other medical data from hospitals treating the injured crash participants, detailed follow-up interviews with crash participants, and computer aided reconstruction of the crash where possible.

Participation in the interviews is voluntary but as CASR is protected from subpoena under Section 64D of the *South Australian Health Commission Act 1976*, CASR is able to promise confidentiality to the crash participants who do consent to an interview. For this reason, participants are able to share their knowledge of the events of the crash without fear that there will be any legal consequences for them in doing so. Nonetheless, participants' descriptions of the crash are always compared to evidence at the scene, evidence from examination of vehicles, and evidence given by other participants or witnesses. In this way we hope to minimise the possibility of erroneous information.

When all the evidence has been collected from these various sources, a review is conducted of each case by a multidisciplinary group of CASR staff to establish factors that contributed to the causation of the crash and the resulting injuries.

Two CASR in-depth crash investigation databases were used for the non-fatal crashes in this study. These were the Rural In-Depth Crash Investigation Database 1998-2000 (see Baldock, Kloeden & McLean, 2008) and the Metropolitan In-Depth Crash Investigation Database 2002-2005. Crashes eligible for inclusion in the rural crash study were those occurring beyond the Adelaide metropolitan area but within 100km of the CBD for which an ambulance was called. Crashes in the metropolitan crash study were those occurring within the Adelaide metropolitan area and for which there was ambulance transport of at least one crash participant.

The Rural In-Depth Crash Investigation Database includes a total of 236 crashes, which were investigated across the years 1998 to 2000. Removal of the fatal crashes (n=55) resulted in a final sample for the present study of 181 crashes. This included 80 single vehicle crashes (45%), 59 midblock multiple vehicle collisions (33%) and 42 intersection crashes (23%). There were 78 crashes (43%) requiring the admission to hospital of at least one crash participant, while the remaining 103 cases (57%) resulted in injury severity levels ranging from non-injury to hospital treatment.

The Metropolitan In-Depth Crash Study includes a total of 298 crashes, which were investigated across the years 2002 to 2005. Removal of fatal crashes (n=21) and those involving suicide attempts (n=5 non-fatal) reduced the final sample for the present study to

272 cases. These comprised 87 intersection crashes (32%), 74 multiple vehicle midblock collisions (27%), 61 pedestrian crashes (22%) and 50 single vehicle crashes (18%). There were 87 crashes (32%) in which at least one vehicle occupant required hospital admission, while the remaining 185 crashes (68%) resulted in an injury severity level of hospital treatment.

The procedure for the CASR in-depth crash investigation component of the study was similar to that for the Coroner's files. The databases for these crashes were already in existence so the two experienced researchers were only required to access the database and review each case according to the same criteria as applied to the Coroner's files.

### 2.3. Definition of 'extreme behaviour'

In addition to recording data associated with the crash, investigators critically examined each crash to determine whether extreme behaviour contributed to the crash and whether the crash was a result of a system failure. For each crash, investigators first determined whether extreme behaviour contributed to the crash according to a specific definition.

Any definition of 'extreme behaviour' relies on drawing an arbitrary line in terms of the risks posed by the road user behaviour. Where possible the authors drew on research literature that has quantified the risk of crash involvement associated with extreme behaviours (i.e. alcohol, speed). It was also important that the behaviours identified as extreme were likely to be deliberate (e.g. a level of speeding high enough that it was likely to be deliberately excessive).

Based on these considerations, a crash was considered to involve 'extreme behaviour' if one of the following conditions was deemed to contribute to the crash:

- A BAC level of 0.150 g/100ml or greater for drivers with a full licence (consistent with Category 3 drink driving penalties) and a BAC level of 0.100 g/100ml or greater for motorcycle riders and drivers with a learner permit or provisional licence.
- Travelling at a speed that is 50% or more over the speed limit (e.g. 90km/h in a 60km/h zone).
- For pedestrians, reckless behaviour or a BAC level of 0.200 g/100ml or greater.
- A combination (two or more) of the following illegal driver behaviours: travelling at a speed of 30-35% or more over the speed limit (e.g. 80km/h in a 60km/h zone), positive for a prescribed drug (THC, MDMA, Methamphetamine), a BAC level of 0.100 g/100ml or greater and deliberate reckless behaviour (e.g. dangerous overtaking). Other circumstances such as driving while unlicensed or disqualified and not wearing a seat belt were also taken into consideration with some personal judgement required.

Note that this set of criteria for extreme behaviour specifies very high levels of alcohol and speeding and that some crashes may involve lower levels of these behaviours that contributed to the crash but which we have not classified as extreme. In such cases (e.g. fully licensed drivers with a BAC from 0.05 to 0.15), the driver or road user is not 100% compliant or safe. Consequently, crashes involving any illegal behaviour that contributed to the crash (such as an illegal BAC or travelling over the speed limit) or to injuries sustained during the crash (e.g. failing to wear a seat belt, failing to restrain a child) were also identified and formed a separate category: 'illegal system failures'. While system failures and extreme behaviour are the main focus of this study, it is important to acknowledge the presence of system failures that also feature illegal road user behaviour, and hence, the range of behaviours on the continuum between the two concepts (system failure and extreme behaviour).

### 3. Results

#### 3.1. System failures and extreme behaviour in fatal crashes

The relative contribution of system failures and extreme behaviours in fatal crashes in South Australia as identified from Coroner's files for the year 2008 is shown in Table 1. Around 43% of fatal crashes were considered to involve extreme behaviour that contributed to the crash. Conversely, 57% of fatal crashes were designated as system failures (including 'illegal system failures'); that is, crashes that were characterised by individuals making simple errors within the road system, resulting in fatal injuries. Nineteen of the 47 'system failure' crashes involved some non-compliance or illegal behaviour by road users but which was not considered to have been at an extreme level.

**Table 1**  
**Summary of the role of system failures and extreme behaviour in fatal crashes, 2008**

Category	N	%
System failure	28	33.7
Illegal system failure	19	22.9
Extreme behaviour	36	43.4
Total	83	100.0

The frequencies for types of extreme behaviours observed in the present study are provided in Table 2. In many of these crashes a combination of extreme behaviours were identified and so the numbers in Table 2 exceed a total of 36. The most common extreme behaviours identified were high-level BACs and high-level speeding behaviour. Reckless driver behaviour mostly involved dangerous overtaking. For pedestrians, reckless behaviour involved obstructing drivers and lying on the road. For those pedestrians lying on the road, it is unknown whether they were conscious or aware of their actions.

**Table 2**  
**Extreme behaviours exhibited by road users for road crashes, 2008**

Extreme behaviours	Number
High BAC	30
High speed	18
Drug use*	11
Reckless behaviour*	9
Unlicensed driving*	4
Failure to wear seat belt*	10
Total	82

\*This behaviour by itself does not constitute extreme behaviour. It occurred in combination with other behaviours in the list.

#### 3.2. System failures and extreme behaviour in non-fatal crashes

The relative contribution of system failures and extreme behaviours in non-fatal crashes in South Australia as identified in CASR's in-depth crash databases is shown in Table 3. It can be seen that extreme behaviour only constitutes a small proportion of non-fatal crashes, both for rural and, particularly, metropolitan areas. Road use behaviour that was illegal, but not classified as extreme, was evident in 17% of rural crashes investigated and approximately

10% of metropolitan crashes. This leaves around three quarters of rural area crashes and over 85% of metropolitan area crashes that were system failures.

**Table 3**  
**Summary of the role of system failures and extreme behaviour in non-fatal crashes**

Category	N	%
Rural injury crashes 1998-2000		
System failure	134	74.0
Illegal system failure	30	16.6
Extreme behaviour	17	9.4
Total	181	100.0
Metro injury crashes 2002-2005		
System failure	236	86.8
Illegal system failure	27	9.9
Extreme behaviour	9	3.3
Total	272	100.0

The 17 rural crashes involving extreme behaviour included 13 single vehicle crashes and four head on collisions. These two crash types are consistent with the extreme behaviours of drivers resulting in loss of control of the vehicle. The nine metropolitan area crashes involving extreme behaviour included four pedestrian collisions, four single vehicle crashes and one right angle crash.

The types of extreme behaviours exhibited by road users in the two samples are summarised in Table 4. Reflecting the definition provided for extreme behaviour, high BACs and high speeds were the most common forms of behaviour in both rural and metropolitan areas.

**Table 4**  
**Extreme behaviours exhibited by road users for non-fatal road crashes**

Extreme behaviours	Rural	Metro
High BAC	8	4
High speed	10	5
Reckless pedestrian	-	1
Drug use*	-	1
Reckless behaviour*	-	1
Unlicensed driving*	1	-
Failure to wear seat belt*	2	-
Total	21	12

## 4. Discussion

The current study is the first to determine the relative contribution of system failures and extreme behaviours in a sample of fatal and non-fatal crashes in South Australia, based on the Safe System approach. Results from this study indicate that very few non-fatal crashes (3% metropolitan, 9% rural) involved extreme behaviour by road users and, even in fatal crashes, the majority (57%) were the result of system failures. These findings suggest some reason for optimism. Consistent with Safe System principles, improvements to the road system can assist in eliminating system failures and consequently reduce the incidence and severity of a large proportion of crashes in South Australia.

The proportion of crashes involving extreme behaviours was higher for fatal crashes than for casualty crashes with a lower injury severity. This finding was expected because higher levels of extreme behaviours such as alcohol use (Li et al., 1997) and speed (Elvik et al., 2004) are generally associated with increased injury severity in a crash. Alcohol intoxication results in reduced cardiac output, greater susceptibility to haemorrhagic shock, and increased pulmonary vascular resistance, all of which can negatively affect the body's response to traumatic injury. Higher travelling speed is linked to a higher impact speed in the event of a crash and therefore greater forces on the human body, leading to higher injury levels. Therefore, as alcohol intoxication and high travelling speed are both linked to higher levels of injury in a crash, analysis of high injury severity (in this case, fatal) crashes is likely to find over-representation of these factors.

There are a number of infrastructure changes that can be applied to the rural road system to minimise injuries resulting from crashes and to achieve a Safe System. In the sample of fatal crashes, all head on crashes (n=11) occurred on undivided roads. For the prevention of head-on crashes the construction of divided carriageways is preferred but, where this is not feasible or adequate, centre wire rope barriers can be installed to separate opposing lanes of traffic. The flexible barrier is designed to deflect vehicles on impact and absorb energy from the vehicle. Swedish research suggests flexible wire rope barriers configured in the centre of an undivided road can produce reductions of up to 76% of fatalities (Larsson et al., 2003).

Around 51% of all fatal crashes and 32% of fatal system failure crashes involved a single vehicle. A study involving simulations of single vehicle run-off road crashes in rural environments found that adequate clear zones to ensure non-injurious impact speeds could not be implemented in most situations (Doecke & Woolley, 2010). Instead, roadside barrier protection in combination with narrower clear zones might provide the most cost effective way to treat rural roadsides to achieve a Safe System.

The Safe System approach emphasises the complementary role of speed management to road-based improvements. Almost half (46%) of the fatal crashes attributable to system failures occurred on roads with a 110 km/h speed limit and a further 25% were on roads with a 100 km/h speed limit. A reduction in the speed limit from 110 km/h to 100 km/h on certain rural arterial roads in South Australia in 2003 resulted in an estimated 20% reduction in casualty crashes and casualties on these roads (Long *et al.*, 2006). Findings from this study suggest that reductions in the speed limit on 110km/h rural roads has the potential to further reduce the incidence and severity of injuries in the event of a crash.

Alcohol intoxication was clearly the most prevalent of all extreme behaviours, with 87% (n=20/23) of fatal single vehicle crashes involving a driver with an illegal BAC level and 71% (n=5/7) of pedestrians killed having a BAC level over 0.150 g/100ml. The latter proportion is especially high for pedestrian crashes. Infrastructure treatments (e.g. flexible roadside barriers and clear zones), speed management techniques (e.g. lower speed limits) and vehicle design features (e.g. electronic stability control, pedestrian friendly design) can only be expected to have a limited impact in reducing the severity of single vehicle and pedestrian crashes involving such extreme behaviours. Alcohol interlocks in all vehicles could provide a system wide approach to preventing drink driving but presents many practical and economic



challenges. The issue of drunken pedestrians provides an even greater challenge because this behaviour is not illegal although police may take action if the pedestrian causes an obstruction to traffic or takes longer than necessary to safely cross the road. Hutchinson et al. (2010) discusses countermeasures to reduce crashes involving intoxicated pedestrians and suggests that the problems of alcohol abuse and of drunk pedestrian crashes overlap and perhaps should be tackled together. The authors also conclude that the greatest gains might be made from making the environment safer for all pedestrians through reductions in speed limits at locations with high pedestrian activity.

#### 4.1. Limitations

A limitation of the study was that the quality and quantity of crash related information in the Coroner's files varied from case to case. In particular, many cases did not provide objective estimates of vehicle travelling or impact speeds based on crash reconstruction techniques (it is acknowledged that this is not always possible). Therefore, it is possible that a small number of cases involving speeding may not have been identified.

The exclusion of seven 'open' fatal crash cases that were under investigation at the time of case identification means that there was not a complete data set for the year 2008. However this should not be viewed as a significant limitation as there is no reason to believe that the excluded cases would be biased in any direction (i.e. no more likely to be a system error than extreme behaviour or vice versa). Future work will involve analysis of these cases once they are 'closed' in addition to another year's worth of fatal data from 2009.

With regard to the CASR in-depth crash investigation data, the case collection for both studies was most commonly conducted during standard office hours (daytime, weekdays). A proportion of cases in each database did occur outside of these times but the databases could not be said to be fully representative in that sense. Of note is that alcohol-related crashes are more common on weekends and at night time, and so the in-depth database will underestimate the proportion of casualty crashes involving road users intoxicated by alcohol. However, the much lower levels of extreme behaviour recorded for the non-fatal crashes in comparison to the fatal ones are unlikely to be due solely to any effects of non-representativeness. There were also a number of cases for which it was not possible, mainly due to insufficient information, to undertake computer-based speed reconstructions. For this reason, some cases involving low-level speeding may not have been identified. This would mean a small degree of undercounting in the tally of illegal system failures.

#### 4.2. Conclusion

In conclusion, a substantial proportion of fatal crashes and the vast majority of non-fatal crashes in South Australia involve people making normal road user errors. They are system failures. Those few that involve extremes of behaviour are more likely to produce fatalities. This is to be expected as high blood alcohol concentrations and high speed, both classified as extreme behaviour, are linked to more severe injury outcomes. Following the Safe System approach, the development of forgiving road and roadside infrastructure, the setting of appropriate speed limits to reduce high injury risks and improvements to safe vehicle design have much potential to reduce the severity of injuries resulting from system failures and, to a lesser extent, extreme behaviours.

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