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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 a Safe System approach (i.e. improvements to road system design to serve compliant road users) is capable of reducing 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.

KEYWORDS

Fatal crash, Accident investigation, Road user behaviour, Coroner

Summary

In Australia, there has been a recent paradigm shift to a Safe System approach that 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. The Safe System approach compels system designers to provide an intrinsically safe environment, representing a shift away from the traditional approach placing responsibility for safety on the road user.

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 the road system more readily than crashes resulting from extreme behaviours. The classification of crash causation in terms of system failures or extreme behaviour is needed to determine the extent to which a Safe System approach (i.e. improvements to road system design to serve compliant road users) is capable of reducing road crash numbers.

To examine the relative contribution of system failures and extreme behaviour in South Australian crashes, two datasets were reviewed: Coroner's investigation files for fatal crashes and databases of in-depth crash investigations conducted by CASR. For each crash in the datasets investigators first determined whether extreme behaviour contributed to the crash according to a specific definition. If extreme behaviour was not a factor, investigators considered what changes could be made to the road transport system, if any, to prevent the crash and prevent the injuries sustained in the crash. Crashes involving extreme behaviour might also be affected by changes to the road system, however for the purposes of this study these concepts were treated as mutually exclusive.

The definition of extreme behaviour specified high levels of alcohol and speeding but some crashes involved lower levels of these behaviours that contributed to the crash (i.e. the road user was not 100% compliant or safe) and were not classified as extreme. In such cases, crashes involving any illegal behaviour that contributed to the crash or to injuries sustained during the crash were identified and formed a separate category 'illegal system failures'.

A summary of the results from the analysis of 83 fatal crashes, 272 non-fatal injury crashes in metropolitan Adelaide and 181 non-fatal rural crashes in South Australia is presented in the following table.

Summary of the role of system failures and extreme behaviour in fatal and non-fatal crashes in South Australia

Data source	Extreme behaviour (%)	Illegal system failure (%)	System failure (%)
Fatal crashes 2008	43.4	22.9	33.7
Non-fatal metropolitan injury crashes 2002-2005	3.3	9.9	86.8
Non-fatal rural crashes 1998-2000	9.4	16.6	74.0

Very few non-fatal crashes involved extreme behaviour by road users. Even for fatal crashes, a large proportion of crashes were 'system failures'. The higher proportion of extreme behaviour in fatal crashes was likely due to higher levels of blood alcohol concentration and speed being related to a high likelihood of death in a crash. These findings suggest that improvements to the road system (i.e. forgiving road infrastructure, appropriate speed limits, and safe vehicle design) can assist in reducing the incidence and severity of a large proportion of crashes in South Australia.

Contents

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 (Turner *et al.*, 2010). 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 minimises these forces and accounts for human errors 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' behaviour by individuals using the road network. 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). For example, Reason et al. (1990) conducted one of the most well known studies that sought to make a distinction between driver errors and violations to provide a better classification system for crash investigators. Errors were defined as the failure of planned actions to achieve their intended goals (slips, lapses, mistakes) while violations were described as deliberate deviations from safe operations. While the authors acknowledged the influence of the wider social context surrounding violations, errors were primarily considered in relation to the cognitive processes of the individual (Reason et al., 1990 p. 1316) and so the study did not address potential system wide interventions.

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. While Safe System design should cater for non-alert and non-compliant road users, there is also a limit to the extent to which infrastructure and vehicle design can accommodate crashes resulting from extreme road user behaviour (Turner et al., 2010). Extreme road user behaviour might require different types of measures.

A classification of crash causation in terms of system failures or extreme behaviour is needed to determine the extent to which a Safe System approach (i.e. improvements to road system design to serve compliant road users) is capable of reducing road crash numbers. 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. For this reason, only non-fatal CASR in-depth crashes were included in the study sample of the present study.

2 Method

2.1 Data sources

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.

2.1.1 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.

The South Australian State Coroner’s Court granted CASR access to Coronial data. The full investigation of a case can take 12 months or longer. The Coroner’s Court does not permit access to coronial cases under investigation (i.e. ‘open’ cases) for research purposes; therefore, all Coroners’ files included in the study were completed or ‘closed’ files. This restriction resulted in the omission of seven open cases from the data set.

2.1.2 CASR in-depth crash investigation

CASR has been conducting at-scene in-depth crash investigation for many years. This study used data from crashes occurring in metropolitan Adelaide (2002-2005) and in surrounding non-urban areas (1998-2000). CASR crash investigation teams are made up of engineers, psychologists and health professionals who travel to the crash scene after being notified about the event on the ambulance radio or ambulance pager. The sequence of events for a crash investigation is as follows:

- Notification of the crash on the SA Ambulance service radio or pager
- Attend the crash at-scene
- Photograph the scene and involved vehicles
- Discussions with police attending the crash
- Mark the positions of the vehicles and any skid or gouge marks
- Brief introduction and discussion with participants and witnesses at-scene (where appropriate)
- Examine the vehicle(s) at the scene and/or elsewhere
- Record video footage of the approach to the crash site from a driver’s perspective
- Make an engineering survey of the crash site.

Follow-up investigations include:

- Obtain the police report on the crash
- Obtain injury information from hospitals
- Conduct a detailed interview with consenting crash participants and witnesses
- Review site design and crash history of the site
- Review crash history of the drivers
- Review Coroners file where appropriate
- Computer aided crash reconstruction where relevant and practicable
- Perform a multidisciplinary case review.

Following the crash, an engineering survey is made of the site to record road geometry, the location of roadside objects and any other relevant information such as line marking and vegetation. Engineering drawings of the road section are also obtained from the responsible road authority. Sites may also be revisited for more detailed follow-up survey work or reassessment from a road engineering perspective.

Follow up vehicle inspections are undertaken to gather any missing information or reconfirm crash injury mechanisms. The information collected for each vehicle includes:

- Photographic record of the vehicle, including detailed photos of any visible damage and evidence of occupant (or pedestrian) contact
- Recording of VIN (Vehicle Identification Number) and current registration details
- Inspection of tyres: dimensions, tread and pressure
- Inspection of seatbelts for condition and load marks
- Measurement of deformation
- Inspection for window tinting and any vehicle modifications.

Follow up personal interviews are conducted whenever possible with those involved in the crash and any witnesses. Participation in 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, interviewers are still vigilant to the possibility of participants either deliberately misrepresenting the crash or describing the crash in terms that preserve their own self-esteem. 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. The information sought during these interviews includes:

- Personal details (age, sex and, for pedestrians, height and weight)
- Driving experience, traffic violation and crash history
- Familiarity with the road and the vehicle driven in the crash
- Trip details
- Possible distractions
- Alcohol and drug use, if any, prior to the crash
- Emotional and fatigue factors

- Pre-existing medical and physical disabilities
- Perception of the crash and its contributing factors
- Immediate injuries and resultant disabilities
- Clarification of vehicle/pedestrian movements, positions and the crash sequence.

Data on injuries are obtained from hospital records. Police accident reports are obtained to provide information about the crash as reported to, and interpreted by, the police. Where appropriate, Coroners files are also examined to check consistency of findings or shed further light with previously unobtainable evidence.

When all the evidence has been collected, 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.

2.2 Inclusion criteria and definitions

2.2.1 Coroner's files

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.

For the purposes of this study, it was important that the fatal crashes included in the study were crashes that occurred within the road transport system and that any fatal injuries sustained were a result of the crash and not other causes. Therefore, motor vehicle crashes resulting in a fatality were included if they satisfied the following criteria:

- The death was reported to the South Australian Coroner's Office and occurred between 1 January 2008 and 31 December 2008.
- The coroner's investigation was completed and formally closed by 1 August 2010.
- The crash occurred on a public road or road related area in South Australia as defined by the Australian Road Rules (1999). Note that fatalities occurring on public roads during official racing events were not included.
- The crash was unintentional (i.e. the crash was not a suicide attempt).
- Death was not the result of natural causes (i.e. death was the result of injuries sustained during the crash, not the result of a pre-existing condition such as a myocardial infarction or cerebrovascular disease).

2.2.2 CASR in-depth crash investigation

Two CASR in-depth crash investigation databases were used for 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 to attend. Crashes eligible for inclusion 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.

For this study, it was decided that the Coroner's files would provide information relevant for fatal crashes and that the advantage of the use of the in-depth data was that it could provide information relevant for non-fatal crashes, which normally are not investigated in much depth. This enables a comparison between fatal and non-fatal crashes for the relative importance of extreme behaviour and system failures.

2.3 The sample

2.3.1 Coroner's files

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% transpired in regional areas and 11% were in remote areas. A similar proportion of crashes occurred during the day (49%) and at night (51%). While more fatal crashes occurred on weekdays (63%) than weekends (37%), there was an average of 10 crashes per day during the week and 16 crashes per day over the weekend. The majority of fatal crashes occurred on sealed (87%) and undivided roads (69%).

2.3.2 CASR in-depth crash investigation

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.

2.4 Research procedure

2.4.1 Coroner's files

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. Road crash fatalities reported to the South Australian Coroner's Court for the 2008 calendar year were identified retrospectively using an internal cause of death coding system. Cases were subsequently excluded if the crash did not satisfy the inclusion criteria. 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).

The Australian Bureau of Statistics Remote Areas classifications were used to classify the geographical locations of the fatal crashes into categories representative of their degree of remoteness. The remote areas structure is based on the Accessibility/Remoteness Index of Australia (ARIA) developed by the National Key Centre for Social Applications of GIS (Trewin, 2001). Scores for the index are calculated based on the distance along a road network the individual must travel to access a defined range of services (e.g., medical care, shopping, social interaction, etc.). See Trewin (2001) for a more complete description. For the present study the five remote area classifications were collapsed into three groups: metropolitan, regional and remote.

2.4.2 CASR in-depth crash investigation

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.

2.4.3 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. If extreme behaviour was not a factor, investigators considered what changes could be made to the road transport system, if any, to prevent the crash and prevent the injuries sustained in the crash. It is acknowledged that crashes involving extreme behaviour might also be affected by changes to the road system. Nevertheless, for the purposes of this study these concepts were treated as mutually exclusive.

To determine whether a crash was caused by extreme behaviours or not, the behaviours of all road users involved in the crash were examined. 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).

With respect to alcohol, studies show that crash risk rises exponentially with increasing blood alcohol concentration (BAC) (e.g. Borkenstein *et al.*, 1964; McLean *et al.*, 1980). For drivers with a BAC of 0.150 g/100ml, the relative risk of crash involvement is approx 15 times higher than for a driver with a zero BAC. Relative crash risks are even higher for novice drivers and motorcycle riders, who need to allocate more cognitive capacity to the driving task. While research has found that high BACs are prevalent among pedestrian fatalities in Australia (e.g. Cairney & Coutts, 2003: 80% exceeding 0.150 g/100ml), there is little research-based evidence demonstrating the effects of alcohol on pedestrian road crossing performance. One simulator-based study reported "some subtle effects" of alcohol on road crossing behaviour for those with a BAC level 0.070 - 0.100 g/100ml (Oxley *et al.*, 2006). High BAC participants took longer to make decisions about crossing a road and decided to cross more often with larger unsafe margins than those with low alcohol levels or no alcohol. Given the limited knowledge base on the effects of alcohol on pedestrian behaviour and that it is not an offence to be walking around with a high BAC[1], any BAC level regarded as 'extreme' should be at least the same level as that chosen for vehicle drivers, if not higher.

Compared to alcohol, a similar relationship has been found between travelling speed and the risk of crash involvement. The risk of crashing increases exponentially with increasing travelling speed: in a 60 km/h speed zone, the risk of a casualty crash doubles with each 5 km/h over the limit (Kloeden et al., 1997). Interestingly, every 5 km/h increase in travelling speed in a 60 km/h speed zone is roughly equivalent to an increase of 0.050 g/100ml BAC (Kloeden & McLean, 1998), such that travelling 20-25km/h over the speed limit is roughly equivalent to the risk associated with a BAC of 0.150 g/100ml. The general public does not yet fully appreciate the risks associated with speeding behaviour as it does with drink driving and this is reflected in the different penalties associated with these behaviours in Australian jurisdictions. As speed limits vary on different road types, it is appropriate for a definition of extreme behaviour to be classified as the amount a speed limit is exceeded by, relative to the speed limit, and expressed as a percentage.

The contributory role of impairment by drugs in road crashes has taken much longer to establish than

[1] While it is not an offence to be walking with a high BAC, it is possible for pedestrians with a positive BAC to incur an expiation fee under the Australian Road Rules if they cause an obstruction (ARR 236) or take longer than necessary to safely cross the road (ARR 230).

that for alcohol. Although studies examining the relationship are affected by various methodological problems, the weight of evidence suggests an increase in crash risk associated with drug use (e.g. Drummer *et al.*, 2004; Dussault *et al.*, 2002) although not to the same extent as alcohol. There are no legal limits set for the three prescribed illegal drugs subject to roadside screening in South Australia (THC, MDMA, Methamphetamine), with any detected presence of a drug being treated as an offence. The main reason for this is that it has been too difficult to identify a level above which drivers are markedly more at risk compared to drivers below that level of drug concentration. Due to the uncertainties associated with drug concentrations and risk, a positive drug test alone is not sufficient to be regarded as extreme behaviour.

Based on the aforementioned literature, 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 3.1. 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. These crashes are theoretically preventable given improvements to the road system. Of the 'system failure' crashes, 40% (n=19) involved some non-compliance or illegal behaviour by road users but which was not considered to have been at an extreme level. These 'illegal system failure' crashes account for 23% of fatal crashes in 2008.

Table 3.1
Summary of the role of system failures and extreme behaviour in fatal crashes, 2008

Category	N	Percentage
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 3.2. In many of these crashes a combination of extreme behaviours were identified and so the numbers in Table 3.2 exceed a total of 36. The most common extreme behaviours identified were high-level BACs and high-level speeding behaviour. Reckless behaviour included mostly dangerous overtaking. In the case of pedestrians, reckless behaviour involved behaviour 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 3.2
Extreme behaviours exhibited by road users for fatal 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 Characteristics of fatal crashes

A series of chi-square tests for independence were conducted to compare the crash causation designation (extreme behaviour, illegal system failure, system failure) across a number of crash and road related characteristics for fatal crashes.

3.2.1 Crash characteristics

Results from the analysis of crash causation category by crash-related characteristics for fatal crashes are presented in Table 3.3. Note that there were small numbers in some cells for these analyses. Statistically significant differences were observed for the location of the crash, crash type, time of day and day of week. A greater proportion (75%) of system failures and illegal system failures (74%) were in rural areas (regional and remote) than the metropolitan area suggesting that simple errors made by drivers in rural environments can more easily result in fatal injuries. In contrast, the majority (61%) of crashes involving extreme behaviour were in the metropolitan area.

Table 3.3
Crash-related characteristics for fatal crashes, 2008

Crash characteristics	Extreme (n=36)	Illegal system failure (n=19)	System failure (n=28)	χ^2	*df*
Location of crash^ [1]					
Metropolitan	22	5	7	10.68**	2
Regional	11	9	20		
Remote	3	5	1		
Crash type^ [2]					
Pedestrian	7	1	3	12.63*	6
Single vehicle	23	10	9		
Multiple vehicle intersection (total)	3	4	8		
Right turn	2	2	3		
Right angle	1	1	4		
Left turn	-	-	1		
Rear end	-	1	-		
Multiple vehicle midblock (total)	3	4	8		
Head on	2	3	6		
U-turn	1	-	1		
Rear end	-	1	-		
Entering or leaving road	-	-	1		
Time of day					
Day	6	12	23	28.88**	2
Night	30	7	5		
Day of week^					
Weekday	14	16	22	15.49**	2
Weekend	22	3	6		

*p<.05, **p<.01
^ One or more cells contain fewer than 5 cases. [1] Regional and remote were combined for the analysis.
[2] The four broad categories were compared in the analysis by crash type.

The majority of pedestrian crashes (64%) and single vehicle crashes (55%) involved extreme behaviour. Six of the seven pedestrian crashes classified as extreme earned their classification due to extreme behaviour by the pedestrian (i.e. alcohol, drugs or a combination). Multiple vehicle crashes were more likely to be the result of system failures, whether they occurred at intersections or midblock locations. Eleven of the 15 fatal multiple vehicle midblock collisions were head-on crashes, all of which occurred on undivided roads. Six of the head-on crashes were classified as system failures.

Analysis of crash times indicated that fatal crashes resulting from extreme behaviour occurred most frequently at night (83%) and on weekends (61%), times associated with high risk behaviours such as alcohol use. Conversely, illegal system failures and system failures were most frequent during the day and on weekdays.

3.2.2 Characteristics of the road environment

Analyses were conducted to explore the relationship between characteristics of the road environment and fatal crash causation. The results of the analyses, shown in Table 3.4, indicate that statistically significant differences were found for speed limit and for road separation status. Crashes attributable to system failures and illegal system failures predominantly occurred on roads with a speed limit of 80 km/h or higher (89%, 84% respectively) and on roads that were undivided (79%, 90% respectively). For crashes involving extreme behaviour, there were no discernable differences by speed limit category or by road separation status. While not statistically significant, crashes resulting from extreme behaviour tended to occur more frequently on arterial roads (50%) and crashes resulting from system failures were more prevalent on highways (46%).

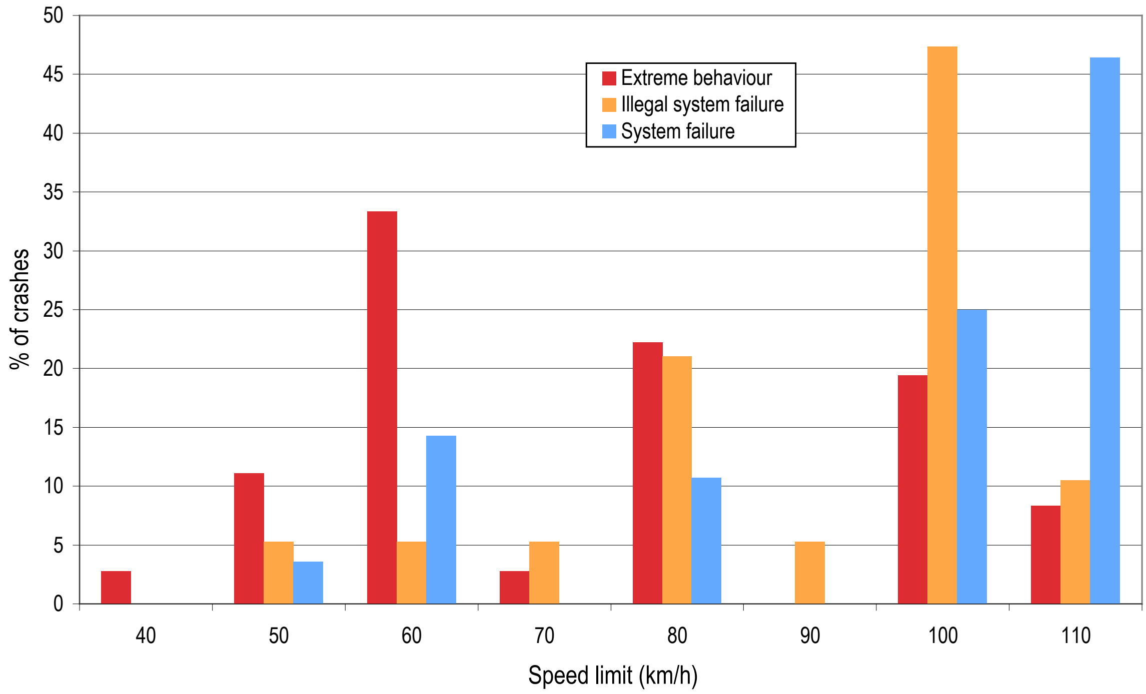
Further analysis of the distribution of speed limits (see Figure 3.1) indicates that a large proportion of system failure (71%) and illegal system failure (69%) crashes were on very high speed roads with 100 and 110 km/h limits compared to extreme behaviour crashes (28%). Perhaps the most striking aspect of the distribution is the 13 crashes (46%) attributable to system failures on 110km/h roads. A reduction in the speed limit on these roads might reduce the injury severity of these crashes. Note that one crash occurred on a 40km/h road which was a temporary speed limit for road works, reduced from 80km/h.

Table 3.4
Road-related characteristics for fatal crashes, 2008

Road characteristics	Extreme (n=36)	Illegal system failure (n=19)	System failure (n=28)	χ^2	*df*
Class of road^					
Highway	8	2	13	10.14	6
Arterial	18	9	9		
Collector	4	3	4		
Local	6	5	2		
Speed limit^					
40-70 km/h	18	3	5	10.33**	2
80-110 km/h	18	16	23		
Road separation^					
Divided	18	2	6	10.93**	2
Undivided	18	17	22		
Road surface^					
Bitumen	33	14	25	3.74	2
Unsealed	3	5	3		
Roadside shoulder^[1]					
Sealed	2	2	6	2.09	2
Unsealed	15	8	13		
N/A (inc. no shoulder)	19	9	9		

*p<.05, **p<.01
^ One or more cells contain fewer than 5 cases. [1] N/A was excluded from the analysis.

Figure 3.1
Distribution of speed limit for fatal crashes, 2008



3.3 Extreme behaviour and system failures 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 3.5. 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, that is, crashes theoretically preventable by a Safe System approach.

Table 3.5
Summary of the role of system failures and extreme behaviour in non-fatal crashes in South Australia

Category	N	Percentage
Rural 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 3.6. Given 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 3.6
Extreme behaviours exhibited by road users
for non-fatal crashes in South Australia

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

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

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 an increased likelihood of injury 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.

Data from the Coroner's investigations of fatal crashes indicated that system failures occurred predominantly in rural areas while crashes resulting from extreme behaviour were concentrated in metropolitan areas. This finding was not surprising given the relatively unforgiving rural road environment in South Australia typically characterised by high speed limits, unprotected roadside hazards such as trees, and no separation of two-way roads. Indeed, further analysis of road characteristics confirmed this view. Fatal crashes involving system failures were significantly more likely to occur on roads with high speed limits and on undivided roads. In such environments, even small errors by road users can result in severe consequences. In addition, 57% (n=16) of fatal system failure crashes involved multiple vehicles, of which eight were at intersections and six were head-on crashes.

An interesting finding was that the characteristics of 'illegal system failure' fatal crashes were more similar to those of 'system failure' crashes than 'extreme behaviour' crashes. Consistent with crashes resulting from system failures, 'illegal system failure' crashes occurred more frequently in rural areas, during the day, on weekends and on undivided roads with high speed limits. This finding reinforces the view that it is appropriate for 'illegal system failure' crashes to be classified in the broader category of 'system failures'.

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). With respect to multiple vehicle crashes at intersections, an OECD report (2008) suggests several solutions to assist in creating a Safe System: lower speed limits in the vicinity of intersections, skid resistant pavement treatments to improve braking, improved intersection controls with roundabouts, traffic signals, platforms or other treatments and the introduction of fully controlled turning movements at traffic signals (the latter is more applicable in metropolitan settings).

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.

In contrast to crashes caused by system failures, fatal crashes involving extreme behaviours occurred predominantly in metropolitan areas (61%), at night (83%) and on weekends (61%). The high incidence of extreme behaviours at night and on weekends is not surprising given that high-risk behaviours such as alcohol intoxication are most prevalent at these times. For instance, records of non-fatal alcohol-related ambulance attendance in Melbourne indicated that the majority of attendances occurred from Friday to Sunday and at night from 6:00pm to 4:00am (Clemens *et al.*, 2009). Further support comes from RBT detection data that suggests that drink driving is most prevalent at night and on weekends in South Australia (Wundersitz *et al.*, 2009).

With respect to crash type, extreme behaviours were predominantly associated with single vehicle crashes or pedestrian crashes. 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. 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.

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). For example, vehicle speeds were often not provided when a sole occupant was killed in a single vehicle crash. 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).

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[2]. 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 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.

FUTURE DIRECTIONS

While the current study provides a good indication of the relative contribution of system failures and extreme behaviour in fatal crashes, the sample was confined to fatal crash data for one calendar year. Increasing the sample size of Coroner's files to include fatal crashes occurring over a longer time frame (i.e. 2-3 years) would be beneficial in providing a clearer understanding of specific crash types and associated risks. It is also conceivable that there may be variation in the types of crashes over time according to external or environmental factors (e.g. economic climate, weather patterns, changes to legislation).

In the context of leading the change to a Safe System approach, crash investigation was described in an OECD (2008) report as "one of the most notable new initiatives (that) goes to the heart of road safety management" (p.111). Using information from the systemic investigation of fatal crashes, system designers from various organisations in Sweden work together using the "OLA" (Objective data, List of solutions, Addressed action plans) method to prevent a fatal crash from happening again. The process involves reviewing facts relevant to the crash, identifying feasible solutions and then stating what they will do, as a matter of public record (OECD, 2008). Based on a subset of crashes from CASR's in-depth investigation database an OLA session was held in South Australia in 2010, involving a number of different authorities. There is a strong case for continuing and expanding this collaborative activity so that a wide range of parties can share the responsibility for improving the safety of the road system in South Australia.

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.

[2] The CASR in-depth database included approximately 48% more non-fatal crashes occurring during day time (9am-6pm) and 27% more non-fatal crashes on weekdays than the non-fatal crashes recorded in the TARS database during the same time period.

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