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The relative contribution of system failures and extreme behaviour in South Australian fatal crashes, 2008-2009

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The relative contribution of system failures and extreme behaviour in South Australian fatal crashes, 2008-2009

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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. 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 (2008-2009) for 189 fatal crashes. The results were compared with data from CASR's in-depth crash investigations for 272 non-fatal metropolitan injury crashes and 181 non-fatal rural crashes. The analysis found that that very few non-fatal crashes (3% metropolitan, 9% rural) involved extreme behaviour by road users and, even in fatal crashes, the majority (54%) were the result of system failures. Fatal crashes resulting from system failures were more likely than those resulting from extreme behaviour to occur during the day, on weekdays, in rural areas and on roads with high speed limits. Findings from the current study suggest that improvements to the road transport system (i.e. forgiving road infrastructure, appropriate speed limits, and safe vehicle design) 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, Safe system

Summary

In Australia, there has been a 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 pro-actively 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 can assist in 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 road crash numbers.

There is a belief in the community that road fatalities and serious injuries are the result of risk taking or extreme behaviour and these crashes can receive extensive media coverage. In 2011 the Centre for Automotive Safety Research (CASR) examined the contribution of system failures and extreme behaviour in the causation of fatal and non-fatal South Australian crashes. The study found that very few non-fatal crashes involved extreme behaviour and even in fatal crashes, the majority were the result of system failures. However, the sample of fatal crashes was confined to data for one calendar year (2008). This current study includes data from Coroner's files for the calendar year 2009, substantially increasing the sample size of fatal 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 (2008-2009) for 189 fatal crashes. The results were compared with data from CASR's in-depth crash investigations for 272 non-fatal metropolitan injury crashes and 181 non-fatal rural crashes. For each crash investigators determined whether extreme behaviour contributed to the crash according to a specific definition. 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 fatal crashes and non-fatal injury crashes in South Australia is given 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 2008-2009	45.5	23.8	30.7
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

This study shows that over half of all fatal crashes and over 90% of non-fatal crashes in South Australia involve people making ordinary road user errors or 'system failures'. Fatal crashes resulting from system failures were more likely than those resulting from extreme behaviour to occur during the day, on weekdays, in rural areas and on roads with high speed limits. Findings from this study 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

1.1 The Safe System approach

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

The Safe System approach acknowledges 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. An integral aspect of the approach is designing infrastructure and vehicles that take into account human errors and minimise impact forces when collisions occur so that road users 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). Johnston et al. (2014, p77) capture the essence of the Safe System approach: "Effective intervention implies proactive innovation".

Ideally, an effective Safe System would have 'alert and compliant' individuals using the road network. Responsible road user behaviour can be promoted through the judicious 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 why road crashes occur. Nevertheless, the system must still be forgiving of those who use the road responsibly but who make mistakes.

1.2 System failures and extreme behaviour

Compliant road users 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' behaviour that lead to crashes. For example, alcohol use and speeding behaviour are associated with exponential increases in the risk of crashing (Borkenstein, Crowther, Schumate, Zeil, & Zylman, 1964; Kloeden, McLean, Moore, & Ponte, 1997).

It is often thought that a large proportion of crashes, particularly fatal crashes, are due to extreme behaviour by drivers. This perception may, to some extent, be reinforced by greater media coverage of 'sensational' fatal crashes involving extreme behaviours such as high speed and excessive alcohol intoxication. However, it is not known what proportion of crashes in Australia can be attributed to extreme behaviour 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, Lenne, Stanton, Jenkins, & Walker, 2010).

Understanding the relative contribution of system failures and extreme behaviours in crash causation has important implications for the improvement of road safety. 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, Cairney, Jurewicz, & McTiernan, 2010). Extreme road user behaviour will require different types of countermeasures.

1.3 The current study

In 2011 the Centre for Automotive Safety Research (CASR) developed one of the first classifications of crash causation in terms of system failures or extreme behaviour in order to determine the extent to which a Safe System approach (i.e. improvements to road system design to serve compliant road users) was capable of reducing road trauma. 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 occurring in 2008 (N=83) and databases of metropolitan and rural in-depth crash investigations conducted by CASR (N=272). Findings were published in the CASR report *"The relative contribution of system failures and extreme behaviour in South Australian crashes"* (Wundersitz & Baldock, 2011).

While the previous study provided 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. It is 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). The current study includes data from Coroner's files for the calendar year 2009 thus increasing the sample size of fatal crashes. This will be beneficial in providing a clearer understanding of the relative contribution of system failures and extreme behaviours in crash causation.

2 Method

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. Through the routine investigation, the state Coroner obtains comprehensive detailed information about the circumstances surrounding a fatal crash. 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 usually 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 2008 and 2009 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 (including motorcycles, bicycles and pedestrians) on a road. 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. a pre-existing condition such as a myocardial infarction). Also, all Coroner's files included in the study were completed or 'closed' files that were no longer under investigation.

2.2 The sample

Closed Coroner's files coded as 'motor vehicle accidents' during 2008 and 2009 were obtained for analysis (2008 N=98, 2009 N=112). In 2008, nine cases did not meet the study inclusion criteria (i.e. suicide, died from natural causes, crash on private property) and in 2009, 12 cases did not meet the criteria. Note that six extra 'closed' cases have been added to the 2008 data reported in Wundersitz and Baldock (2011). The final sample included 189 fatal crashes resulting in 212 fatalities.

In this sample of fatal crashes 12% involved a vehicle colliding with a pedestrian, 52% involved a single vehicle and 37% were the result of a multiple vehicle collision of which 45% occurred at intersections and 55% were midblock. Around 36% of fatal crashes occurred in metropolitan areas, 53% in regional areas and 11% in remote areas.

2.3 Research procedure

The research design involved the examination of road crashes resulting in fatal injuries for a two year period to determine the proportion of crashes attributable to system failures and extreme behaviour. Three road safety experts with many 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, investigators reviewed all cases together to ensure concordance.

A crash-based 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/helmet 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).

2.4 Definition of 'extreme behaviour'

Investigators critically examined all known details about each crash to determine whether extreme behaviour contributed to the crash or whether the crash was a result of a system failure. For each crash, investigators 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 (for details see Wundersitz and Baldock, 2011) 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 in South Australia) 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 judgment 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 (e.g. an illegal BAC, travelling over the speed limit, drug use) 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 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 189 fatal crashes in South Australia as identified from Coroner's files from 2008 to 2009 is shown in Table 1. During 2008 and 2009, 46% of fatal crashes were considered to involve extreme behaviour that contributed to the crash. Conversely, 54% 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. 'Illegal system failure' crashes, involving some non-compliance or illegal behaviour by road users but which was not considered to have been at an extreme level, accounted for 24% of fatal crashes.

There was a slight variation in percentages for crash causation categories by year with a small increase in extreme behaviour crashes and a corresponding decrease in system failure crashes in 2009, but the difference was not statistically significant (χ^2=0.79, *df*=2, *p*<0.67). Consequently, the results from the 2009 data confirm the results found in the previous study based on 2008 data.

Table 1
Summary of the role of system failures and extreme behaviour in fatal crashes, 2008-2009

Crash causation category	2008 (N=89)	2009 (N=100)	Total (N=189)
System failure	33.7% (n=30)	28.0% (n=28)	30.7% (n=58)
Illegal system failure	23.6 %(n=21)	24.0% (n=24)	23.8% (n=45)
Extreme behaviour	42.7% (n=38)	48.0% (n=48)	45.5% (n=86)

The frequencies for types of extreme behaviours observed in this study are presented in Table 2. In many of these crashes a combination of extreme behaviours were identified and so the numbers in Table 2 exceed the total of 86 (see Table 1). The most common extreme behaviours identified were high-level BACs, evident in 36% (n=67/189) of all fatal crashes, and high-level speeding (20%, n=37/189, of fatal crashes). Reckless driver behaviour most frequently involved dangerous overtaking and drag racing while reckless pedestrian 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. Failure to wear a seat belt was considered an extreme behaviour, in combination with other behaviours, only if the fatally injured vehicle occupant was not wearing a seat belt.

Table 2
Number of extreme behaviours exhibited by road users for road crashes, 2008-2009

Extreme behaviours	2008	2009	Total
High BAC	30	37	67
High speed	18	19	37
Drug use[a]	11	13	24
Reckless behaviour[a]	9	6	15
Unlicensed driving[a]	4	10	14
Failure to wear seat belt[a]	10	16	26
Total (N)	82	101	183

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

The relative contribution of system failures and extreme behaviours was also investigated for a sample of non-fatal crashes in South Australia as identified in CASR's in-depth crash databases. Full details of the sample and data collection procedures are described in Wundersitz and Baldock (2011). For comparative purposes, a summary of the results from the analysis of non-fatal injury crashes in metropolitan Adelaide and non-fatal rural crashes in South Australia are presented with the fatal crash results from the present study by crash causation category in Table 3. Very few non-fatal crashes involved extreme behaviour by road users both for either rural (9%) or, particularly, metropolitan areas (3%). Road user behaviour that was illegal, but not classified as extreme, was evident in 17% of rural crashes investigated and 10% of metropolitan crashes. The majority of non-fatal crashes in the metropolitan area (87%) and rural regions (74%) were system failures.

Table 3
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 2008-2009 (N=189)	45.5	23.8	30.7
Non-fatal metropolitan injury crashes 2002-2005 (N=272)	3.3	9.9	86.8
Non-fatal rural crashes 1998-2000 (N=181)	9.4	16.6	74.0

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

Analyses were conducted to explore the relationship between crash-related characteristics and fatal crash causation. The results of the analyses for fatal crashes 2008-2009, presented in Table 4, indicate that statistically significant differences were observed for the location of the crash, crash type, time of day and day of week. A greater proportion of system failures (76%) and illegal system failures (67%) 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.

The majority of fatal crashes involving a pedestrian (55%) and a single vehicle (54%) were the result of extreme behaviour. Ten of the twelve pedestrian crashes classified as extreme received their classification due to extreme behaviour by the pedestrian (i.e. alcohol, drugs or a combination). Multiple vehicle crashes were more likely to involve system failures, particularly at midblock locations. The majority (61%) of the multiple vehicle midblock collisions were head-on crashes, of which all but one crash occurred on an undivided road. Thirteen (57%) of the 23 head-on crashes were classified as system failures.

Examination of crash times indicated that fatal crashes resulting from extreme behaviour occurred most frequently at night (78%) and on weekends (57%), times associated with high risk behaviours such as alcohol use. In contrast, illegal system failures and system failures were most frequent during the day and on weekdays.

Table 4
Crash-related characteristics for fatal crashes, 2008-2009

Crash characteristics	Extreme (n=86)	Illegal system failure (n=45)	System failure (n=58)	χ^2	*df*
Location of crash[a]					
Metropolitan	39	15	14	7.0*	2
Regional	34	25	41		
Remote	13	5	3		
Crash type[b,c]					
Pedestrian	12	2	8	16.0*	6
Single vehicle	53	24	21		
Multiple vehicle intersection (total)	9	11	11		
Right turn	6	6	3		
Right angle	3	4	6		
Left turn	0	0	1		
Rear end	0	1	1		
Multiple vehicle midblock (total)	12	8	18		
Head on	5	5	13		
U-turn	1	0	1		
Rear end	3	1	1		
Entering or leaving road	1	1	3		
Sideswipe	2	1	0		
Time of day					
Day	19	26	47	50.1**	2
Night	67	19	11		
Day of week					
Weekday	37	37	44	25.8**	2
Weekend	49	8	14		

*p<.05, **p<.01

[a] Locations were classified using the ABS Remote Areas classifications (Trewin, 2001). Regional and remote were combined for the analysis.

[b] The four broad categories were compared in the analysis by crash type.

[c] One or more cells contain fewer than 5 cases.

3.2.2 Characteristics of the road environment

Results from the analysis of fatal crash causation category by characteristics of the road environment are shown in Table 5. Statistically significant differences were found for class of road and for speed limit. Crashes resulting from extreme behaviour tended to occur more frequently on arterial roads (43%) while crashes resulting from system failures were more prevalent on highways (47%) with very few occurring on local roads (9%). Crashes attributable to system failures and illegal system failures predominantly occurred on roads with a speed limit of 80 km/h or higher (81%, 78% respectively).

Further analysis of the distribution of speed limits revealed that the majority of system failure (60%, n=35) and illegal system failure (51%, n=23) crashes were on very high speed roads with 100 and 110 km/h limits compared to extreme behaviour crashes (38%, n=33). Of importance, 24 crashes (41%) attributable to system failures were on 110km/h roads. A reduction in the speed limit on these roads might reduce the injury severity of these crashes.

Table 5
Road-related characteristics for fatal crashes, 2008-2009

Road characteristics	Extreme (n=86)	Illegal system failure (n=45)	System failure (n=58)	χ^2	*df*
Class of road[a]					
Highway	22	9	27	13.2*	6
Arterial	37	20	20		
Collector	8	4	6		
Local	19	12	5		
Speed limit					
40-70 km/h	39	10	11	13.6**	2
80-110 km/h	47	35	47		
Road separation					
Divided	27	9	10	4.37	2
Undivided	59	36	48		
Road surface					
Bitumen	79	38	53	2.0	2
Unsealed	7	7	5		
Roadside shoulder[b]					
Sealed	9	10	11	3.1	2
Unsealed	39	17	27		
N/A (inc. no shoulder)	38	18	20		

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

4 Discussion

The current study is the first to determine the relative contribution of system failures and extreme behaviours in a sizable sample of fatal and non-fatal crashes in South Australia, based on the Safe System approach. Results from this study indicate that for fatal crashes, the majority (54%) were the result of system failures (including illegal system failures) with very few non-fatal crashes (3% metropolitan, 9% rural) involving extreme behaviour by road users. Evidently, people make simple mistakes when using the road system and this can lead to serious injuries, much more frequently than those resulting from extreme behaviours. 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 relative contributions reported in this study confirm the findings reported in the previous CASR study (Wundersitz & Baldock, 2011) that examined fatal crash data for only a single year (2008). Interestingly, in comparison to the 2008 data, the fatal crash data from 2009 showed a small increase in the proportion of crashes due to extreme behaviour and a decrease in crashes resulting from system failures although the difference was not statistically significant. It is reasonable to expect a decrease in system failure crashes over time if road safety strategies target compliant road users, resulting in a safer road system (i.e. better infrastructure, more vehicles with better safety features).

The proportion of crashes involving extreme behaviours was higher for fatal crashes than for casualty crashes with a lower injury severity. This finding is perhaps not surprising given that higher levels of extreme behaviours such as alcohol use (Li, Keyl, Smith, & Baker, 1997) and speed (Elvik, Christiansen, & Amundsen, 2004) are associated with an increased likelihood of injury and increased severity in a crash. An important implication of these findings is developing policies and countermeasures based purely on the causes of fatal crashes is misleading.

Road safety strategies need to be proactive and consider the wider road system, where simple errors are being made by ordinary road users, rather than react to the less frequent but headline grabbing extreme behaviours. These findings also reinforce Wegman's (2012, p.28) view of crash causation and how it relates to road safety policy, based on his observations in Europe and Australia "... injury crashes are telling a different story from fatal crashes. This means that we cannot rely only on fatal crash data when formulating road safety strategies. We need to include injury crash analysis as well".

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 weekdays and on 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'. It also suggests that there are road users who are generally compliant but occasionally contravene road rules, probably without serious intent.

Fatal crash data indicated that system failures occurred predominantly in rural areas. This finding can be attributed to 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. In such environments, even small errors by road users can result in severe consequences. In addition, 57% of head-on crashes were classified as system failures, of which all but one head-on crash occurred on an undivided road.

A number of infrastructure changes can be applied to the road system to minimise injuries resulting from crashes and to achieve a Safe System. 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, Candappa, & Corben, 2003).

Around 52% of all fatal crashes and 36% 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 such as wire rope barriers in combination with narrower clear zones might provide the most cost effective way to treat rural roadsides to achieve a Safe System. In-vehicle technology also offers potential system wide solutions to reduce the severity of such crashes. For example, forward collision sensing and avoidance systems can warn or apply braking when they detect other vehicles or pedestrians that cross the projected path of the vehicle. Anderson et al. (2011) estimate that the use of such systems can result in a 16% reduction in fatal crashes, based on NSW crash data.

The Safe System approach emphasises the complementary role of speed management to road-based improvements. Almost half (41%) of the fatal crashes attributable to system failures occurred on roads with a 110 km/h speed limit and a further 19% 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, Kloeden, Hutchinson, & McLean, 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 at night (78%) and on weekends (57%). The high incidence of extreme behaviours at these times is expected given that high-risk behaviours such as alcohol intoxication are also most prevalent at these times (Clemens et al., 2009; Wundersitz, Hiranandani, & Baldock, 2009).

Alcohol intoxication was clearly the most prevalent of all extreme behaviours, with 36% of all fatal crashes and 78% (n=67/86) of ‘extreme’ crashes involving a driver with a high BAC. Furthermore, 75% (n=9/12) of pedestrians killed in a crash resulting from extreme behaviour had a BAC level over 0.150 g/100ml. Infrastructure treatments (e.g. flexible roadside barriers and clear zones), speed management (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 these 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. Nevertheless, Anderson et al. (2011) estimated the use of alcohol interlocks would result in a 15% reduction in fatal crashes in Australia. 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 'open' fatal crash cases that were under investigation at the time of case identification means that there was not a complete data set for 2008-2009. 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. 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. Consequently 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 Conclusions

In conclusion, this study shows that over half of all fatal crashes and over 90% of non-fatal crashes in South Australia involve people making ordinary road user errors or system failures. The crashes that involve extreme 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 the increased use of in-vehicle safety technology have much potential to reduce the incidence and severity of injuries resulting from system failures and, to a lesser extent, extreme behaviours.

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