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A Safe System analysis of serious injury and fatal crashes

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Abstract

Currently, there is limited understanding of the differences in system failure between fatal crashes and those that result in serious injuries. Serious injuries account for the greatest proportion of the social costs of New Zealand's road trauma. This research compared the circumstances of serious and fatal crashes, using a Safe System analysis framework, including the proportion of crashes where 'reckless behaviour' was exhibited. Following a scan of literature to guide the method, a Safe System analysis framework was developed, tested, and applied to 200 serious injury crashes and 100 fatal crashes involving light vehicle occupants. This included criteria for 'triggering' each system pillar. For the user pillar 'reckless behaviour' was also identified using an agreed set of criteria, and for the other pillars extraordinary factors were also identified. For both serious injury and fatal crashes there was significant involvement by all four pillars of the Safe System across the 300 crashes but serious injury crashes were less likely to involve all four pillars of the Safe System. Fatal crashes had a higher proportion of roadside objects and other vehicles struck, were more likely to involve narrow shoulders for run-off road crashes, were more likely to involve centreline crossing crashes on 100 km/h roads, and typically happened in higher speed environments. New vehicles typically had better outcomes in two-vehicle crashes and SUV's/4WD's and utes were more likely to roll-over. Multiple user factors were more likely in fatal crashes. Consistent with overseas literature, reckless behaviour was less common in serious injury crashes and across fatal and serious crashes, multiple system failures as opposed to reckless behaviour was more common. The research shows that serious injury crashes are less likely than fatal crashes to involve complete system failure and that all pillars of the Safe System require attention if tangible road safety improvements are to be expected.

1. Introduction

Currently, there is limited understanding about the circumstantial differences between fatal crashes and those that result in serious injuries. This is of interest as serious injuries account for the greatest proportion of the social costs from New Zealand's road trauma. This study utilises the Safe System approach to more holistically analyse crashes with all aspects of the system in mind. The Safe System approach emphasises, among other concepts that the road environment needs to be more accommodating of human error and that people are vulnerable to crash forces. It examines the entire road system to improve safety by creating safer roads and roadsides, safer speeds, safer vehicles, and safer road use (Ministry of Transport 2010).

Previous research suggests that there could be considerable differences in the nature of fatal and serious crashes (Stigson, Kullgren et al. 2011, Wundersitz and Baldock 2011), which may have implications for initiatives aimed at reducing road trauma.

To date in New Zealand, analyses of serious and fatal crashes, based on Crash Analysis System (CAS)[1] data typically report isolated factors associated with crashes and do not take a Safe System view. To the best of our knowledge, a study of this type has not been conducted in New Zealand to date. Therefore, in this study the potential to compliment CAS information with other available data such as the Australasian New Car Assessment Program (ANCAP) ratings, vehicle safety features, and road speed and risk information was identified. The research questions were:

- Are there differences in the circumstances that lead to fatalities or serious injuries in New Zealand's light vehicle crashes?
- What proportion of crashes result predominantly from system factors as opposed to reckless behaviours?

2. Methods

2.1. Literature Scan

Firstly, a brief scan of the literature was held to determine the methodologies used for studies which compared fatal and serious crashes. Seven studies were used to inform our method. They are briefly described below.

Use of car crashes resulting in injuries to identify system weaknesses (Stigson, Kullgren et al. 2011):

Using a combination of three data-sets this study aimed to find the reason for injury (fatal or serious injury) occurrence, rather than the cause of a crash. Therefore, different components and combinations of the system were examined: the road, the vehicle, and/or the road user. Importantly, for each case, two questions were posed: 1) Did the crash involve noncompliance with the road criteria, vehicle criteria, and/or road user criteria?; and 2) For crashes where more than one of the three components does not comply with the safety criteria, are all of the components correlated to the injury outcome?

Why do people die in road crashes? (de Pont 2016):

This New Zealand study examined 122 fatalities from 2014-2015 which involved cars, trucks, and motorcycles. Using Traffic Crash Reports (TCR) and Serious Crash Unit (SCU) reports, the crashes were categorised by vehicle type (truck, car, motorcycle), and if they occurred in a rural, or an urban setting.

The relative contribution of system failures and extreme behaviour in South Australian crashes (Wundersitz and Baldock 2011):

The aim of the study was to investigate the relative contribution of 'system failures' and 'extreme behaviour' in South Australian crashes from the 2008 calendar year. The report highlighted that for a large proportion of crashes, the incidence and severity of crash outcomes could be reduced by improvements in the 'system' (i.e. improvements to road system design to serve compliant road users).

[1] A database of crash information from Police Reports and Serious Crash Unit investigation reports. It is managed by the New Zealand Transport Agency and provides the user with tools to analyse crashes.

Safe system evaluation of the Christmas/New Year Holiday road toll 2016/17 (Mackie and Scott 2017)

Using a Safe System framework, this report examined the road fatalities for the Christmas/New Year 2016/2017 period in New Zealand. To achieve this, Traffic Crash Reports were analysed, and other vehicle and road related safety information were gathered for each crash. A key finding was that for most crashes, rather than the extreme behaviours that might be expected from the holiday period, most crashes resulted from multiple system failures in relatively conventional circumstances.

High-risk drivers in fatal and serious crashes (Ministry of Transport 2012)

In this New Zealand-based study, data from 2006-2010 were gathered from the CAS system and were filtered for at-fault drivers (based on the CAS-assigned crash cause factors) only. The report compared patterns of high-risk, at-fault drivers with other at-fault drivers in New Zealand in fatal and serious crashes. The study also used in-depth data pertaining to a person's previous convictions (i.e. repeat alcohol offences, evading enforcement, repeat speed offences).

The Safest System: Preventing crashes by preventing errors (Hatfield and Brown 2016):

Data from 94 crashes occurring between March 2010 and February 2013 were obtained. A mixed-methods protocol included interviews with vehicle occupants, and a thorough investigation of the vehicle and crash location using a team of behavioural, road safety, and forensic experts.

Risky driving habits and motor vehicle driver injury (Blows, Ameratunga et al. 2005):

This study used cross-sectional data from the New Zealand Blood Donors' Health Study with the New Zealand Health Information Service's 'National Minimum Dataset' to examine the relationship between risky driving habits, prior traffic convictions, and motor vehicle injury.

The seven studies described above each went some way to informing our method. For example:

- Different components of the system, such as roads, vehicle, and the user were examined (Stigson, Kullgren et al. 2011, Wundersitz and Baldock 2011, Hatfield and Brown 2016, Mackie and Scott 2017);
- Vehicle safety ratings were recorded (Stigson, Kullgren et al. 2011, Mackie and Scott 2017);
- A road classification system was used to determine the level of infrastructure risk (Stigson, Kullgren et al. 2011);
- Non-compliant road users were noted, as were the factors that contributed to this status (i.e. alcohol use and speed) (Blows, Ameratunga et al. 2005, Stigson, Kullgren et al. 2011, Wundersitz and Baldock 2011, Ministry of Transport 2012); and
- The use of Traffic Crash Reports (TCR) as a data source (Ministry of Transport 2012, de Pont 2016, Mackie and Scott 2017);

2.2. Dataset selection

The primary data were obtained from the Transport Agency's Crash Analysis System (CAS). The output from CAS is in the form of Traffic Crash Reports (TCR), which are prepared by the officer who attended the scene. CAS also contains Serious Crash Unit (SCU) reports, which are prepared for all fatal crashes, but rarely for serious injury crashes. To ensure the equal comparison of fatal and serious crashes, SCU reports were not used in this analysis. A crash list was extracted from CAS for the period 1/7/2015 - 30/6/2016. Exclusions were applied so that only fatal and serious crashes, and only drivers and passengers were included in the search. In addition, vehicles involved in a crash were limited to: car/station wagon, taxi, van or utility, or SUV/4WD. Drivers of light vehicles who were under 16 years of age were excluded from the study. This approach was not to minimise the importance of crashes involving these conditions, but rather to focus on a relatively homogenous dataset that would allow meaningful comparison of fatal vs serious crashes. Using random selection, 100 fatal and 200 serious injury crashes were selected for analysis. 2.3. Analysis procedure

A primary goal for the analysis was to categorise the available information from each crash report (TCR) into the four Safe System pillars (Organisation for Economic Co-operation and Development 2008, Ministry of Transport 2010, Larsson and Tingvall 2013). By doing this, the involvement of each pillar in the crash could be 'triggered' so that the predominant factors implicated in fatal and serious injury crashes on New Zealand's roads could be better understood. To guide the analysis, a detailed coding framework based on the Safe System pillars was developed in conjunction with the multi-agency project steering group. It is shown below in Figure 1.

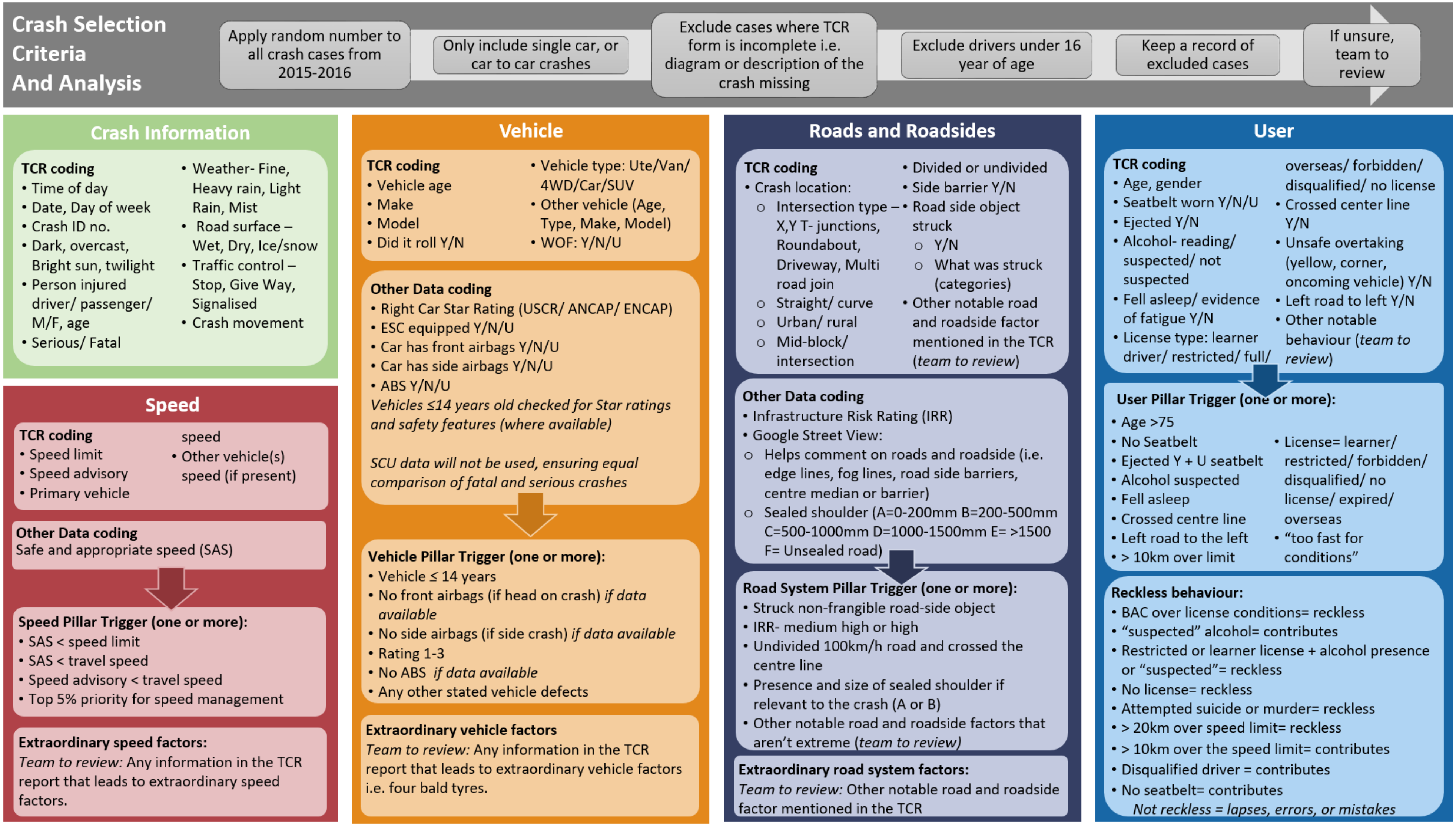
In many instances, information available in the TCR had to be taken at face-value. We acknowledge occasionally, information was missing or there may be questions about its accuracy.

For vehicle factors, the RightCar website - which provides ratings for cars based on the Australasian New Car Assessment Program (ANCAP) - was used to estimate vehicle safety features. The Transport Agency's Speed Management database was also used to determine speed and road environment factors, such as the Safe and Appropriate Speed (an estimate of the speed limit that should exist, given road risk features), and the Infrastructure Risk Rating (IRR), developed by the NZ Transport Agency, which provides an estimate of road risk based on road features. As Figure 1 shows, where applicable, extraordinary vehicle factors mentioned in the TCR (i.e. four bald tyres) were also noted.

A secondary goal was to apply the Wundersitz and Baldock (2011) approach of broadly determining the proportion of fatal and serious crashes that have extreme/reckless behaviours as key factors, versus those where a relatively equitable contribution of system factors were at the heart of crash outcomes. However, where Wundersitz and Baldock (2011) used three categories to identify the factors at the heart of the crash ('extreme behaviour', 'system failure', and 'illegal system failure'), in this study only two categories were used ('system failures', and 'reckless behaviours'). The term 'reckless' was chosen as it better reflects the actions of many drivers who, either unusually or regularly, operate outside of the system that is deemed to be safe. Under the user pillar, a set of rules for 'reckless' behaviour in a crash was determined, with a range of factors that could 'trigger' that option (Figure 1). Sensitivity within this approach was included so that more serious factors (e.g. more than 20 km/h over speed limit) immediately triggered reckless behaviour, whereas at least two less serious factors (e.g. 10-20 km/h over the speed limit) was needed to trigger reckless behaviour.

For the speed pillar, where travel speed was used, it was based on the Police officer's estimation of travel speed from their on-site inspection. There are obvious limitations to the accuracy of this information, but this was used simply to trigger the pillar rather than for quantitative manipulation.

Figure 1. Coding framework for each crash



3. Results

To summarise the involvement of the safe system pillars, Figure 2 shows the proportion of fatal and serious crashes where each pillar was triggered using the evaluation framework outlined earlier. Overall, there is a high degree of involvement across the system pillars, and Figure 3 shows how, in the majority of crashes, three or four pillars were implicated in the crash. Interestingly, there were more fatal crashes where all four pillars of the Safe System failed. This reflects contemporary accident theory (such as James Reason's Swiss Cheese Model (Reason 1990)), which holds that adverse events occur when multiple system failures allow them to. Please note that whilst the involvement of most pillars was similar between fatal and serious crashes, the factors that trigger those pillars, as presented in Figures 4, 5, 6, and 7 below tell a different story. This is worth noting because even though there is a common understanding that many factors are relevant to many crashes, this study gives a more detailed breakdown of which factors seem to be important in understanding the difference between the severity of crash outcomes.

Figure 2. Involvement of system pillars

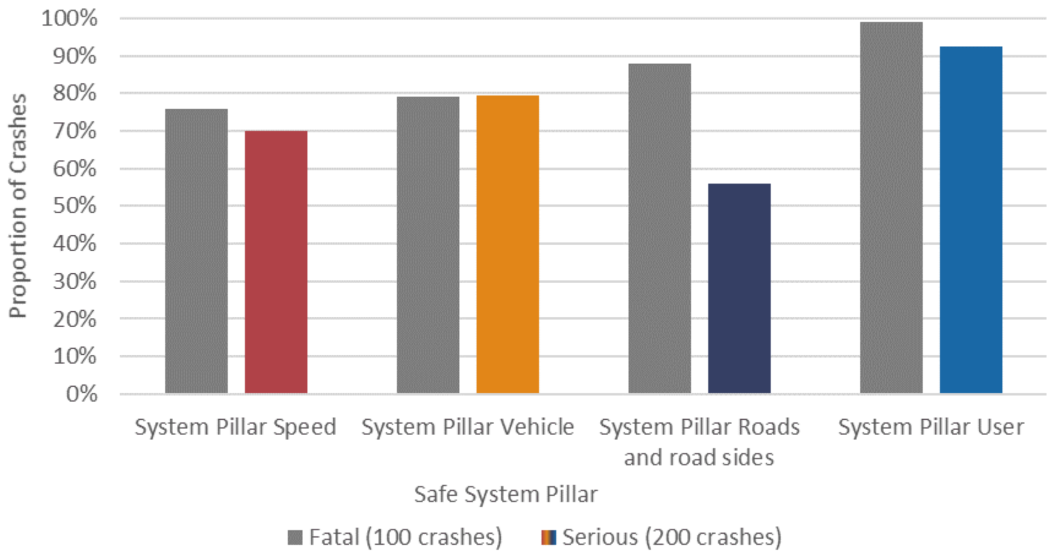


Figure 3. Proportion of crashes involving multiple system pillars

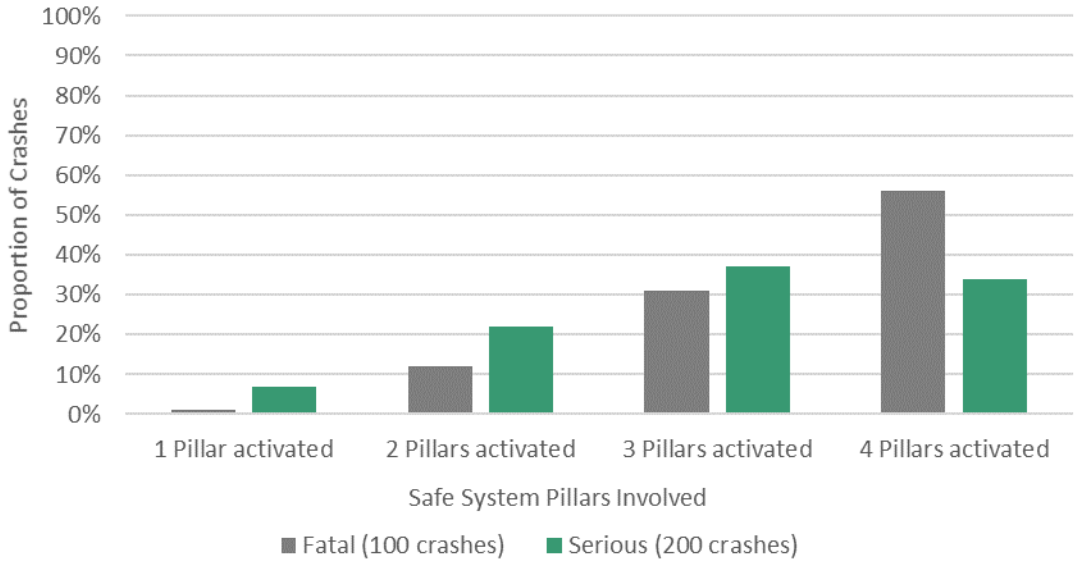
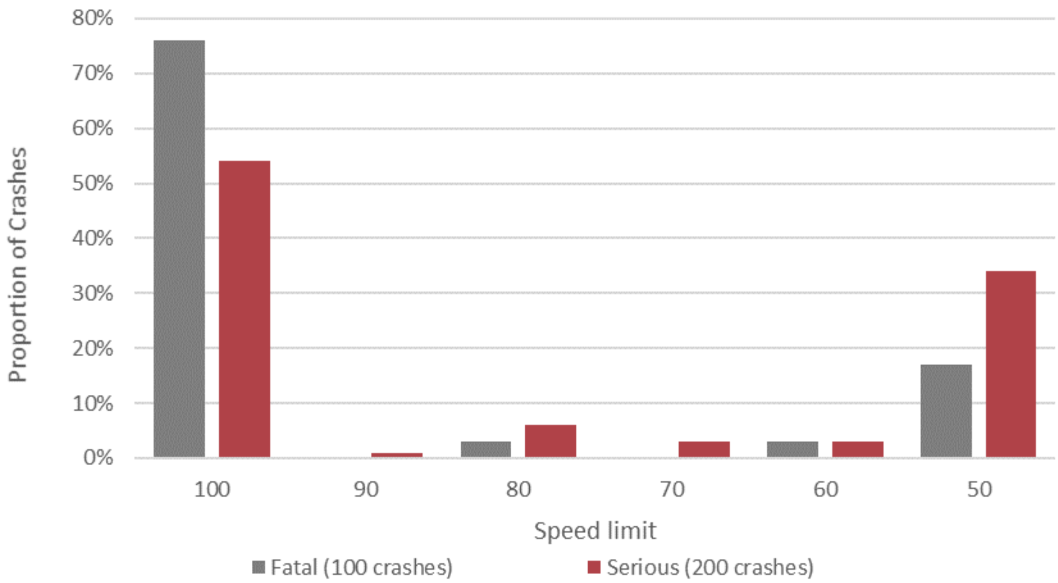


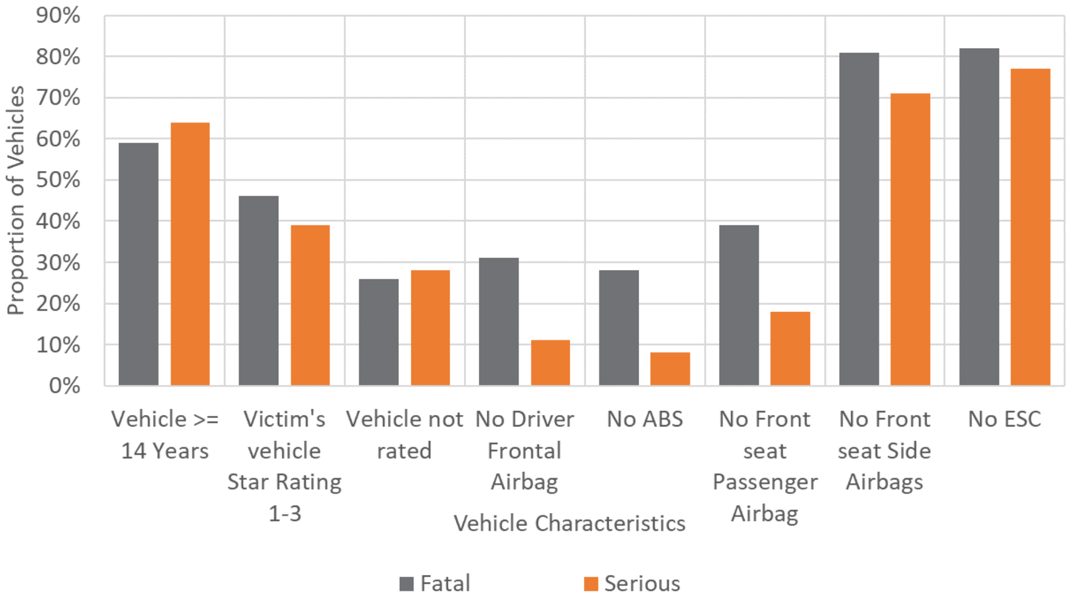
Figure 4 describes speed factors associated with the crashes in the sample. Of the fatal crashes, 76% were in 100km/h environments whereas a much lower proportion (54%) of serious injury crashes were at 100km/h locations, with proportionately more serious injury crashes happening in urban environments. In addition, for crashes in 100km/h environments, the speed limit, and/or the travel speed was often higher than the 'Safe and Appropriate Speed' as defined by the Transport Agency's speed management database. Accordingly, the opposite trend exists for 50km/h environments. This finding is not surprising and reflects the MOT Motor Vehicle Crashes in NZ data (Ministry of Transport 2016) which shows that 73% of fatal crashes are in open road environments and 40% of injury crashes are on urban roads. Collectively, these findings reinforce that the crash forces associated with travel speeds in 100km/h speed limits are less likely to be survivable.

Figure 4. Speed limit at crash location



For vehicles (Figure 5), a greater proportion of fatal crashes had no driver or passenger frontal airbag, or no ABS. For a high proportion of both fatal and serious crashes there were no front-seat side airbags, reflecting the relatively aged fleet.

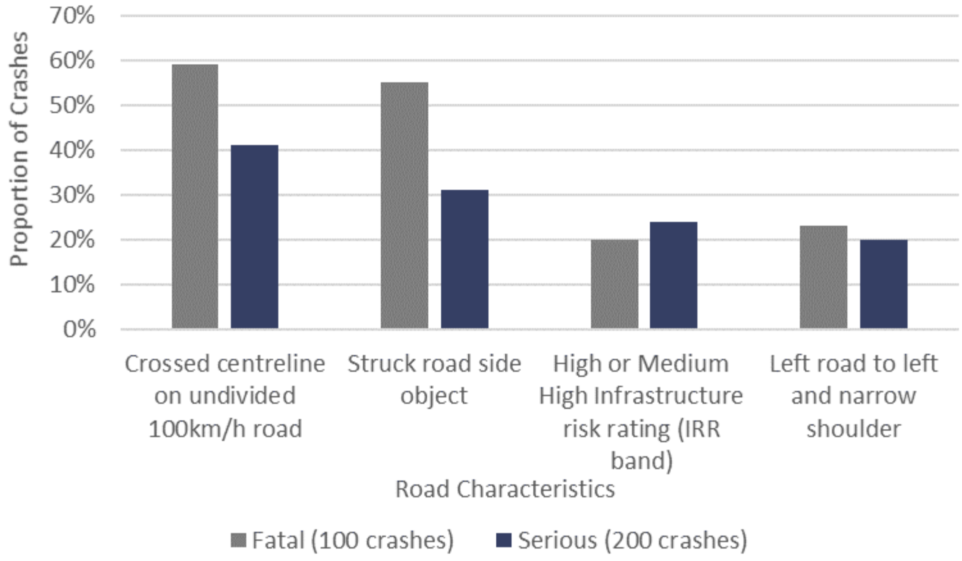
Figure 5. Vehicle characteristics



This suggests that as today's modern vehicles become more widespread in the fleet, there is likely to be a continued fleet safety improvement as a greater number of them have protecting airbags for a range of crash types.

Figure 6 below shows that 59% of fatalities where the centreline was crossed were on undivided high-speed roads (compared with 41% of serious injury crashes). In addition, in 55% of the fatalities, a roadside object was hit, compared to 31% of serious injury crashes. This reflects the high crash forces that are more likely in fatal crash situations and suggests that due to the unforgiving nature fo the object that was struck, there is a higher liklihood that the crash will result in a fatal outcome. Please note that the categories depicted in Figure 6 are not mutally exclusive, and that a crash may have involved multiple factors.

Figure 6. Road and crash characteristics



We found that the user pillar (Figure 7) was often triggered by several factors, with fatal crashes more often having multiple factors involved. For example, 54% of those not wearing seatbelts also either tested positive for alcohol, or were suspected of alcohol impairment. Likewise, 26% of those not wearing seatbelts were also speeding in a reckless manner (>20km/h over limit). Please note that the categories depicted in Figure 7 are not mutually exclusive, for example most of those who were ejected were also not wearing a seatbelt.

Figure 8 shows that approximately half of the fatal crashes involved reckless behaviour. However, for serious injury crashes this proportion was much lower. Overall, although some rules were altered in the present study, this finding is reflected by , who also found a greater proportion of extreme behaviour in fatal crashes. Nevertheless, across both fatal and serious crashes, 'system failure', where there was no evidence of reckless behaviour was more common.

Figure 7. User factors

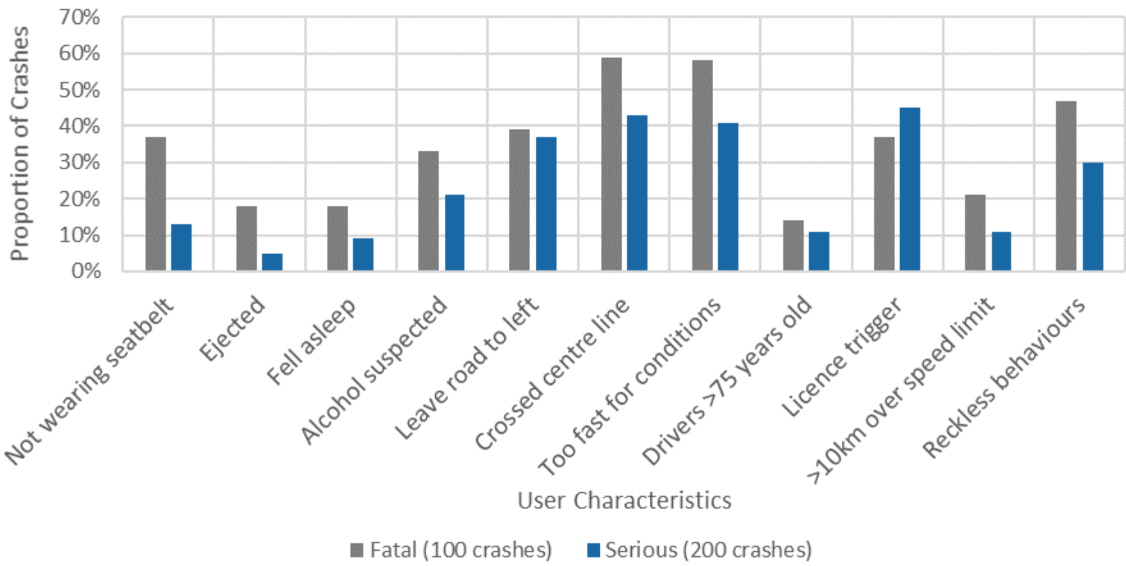
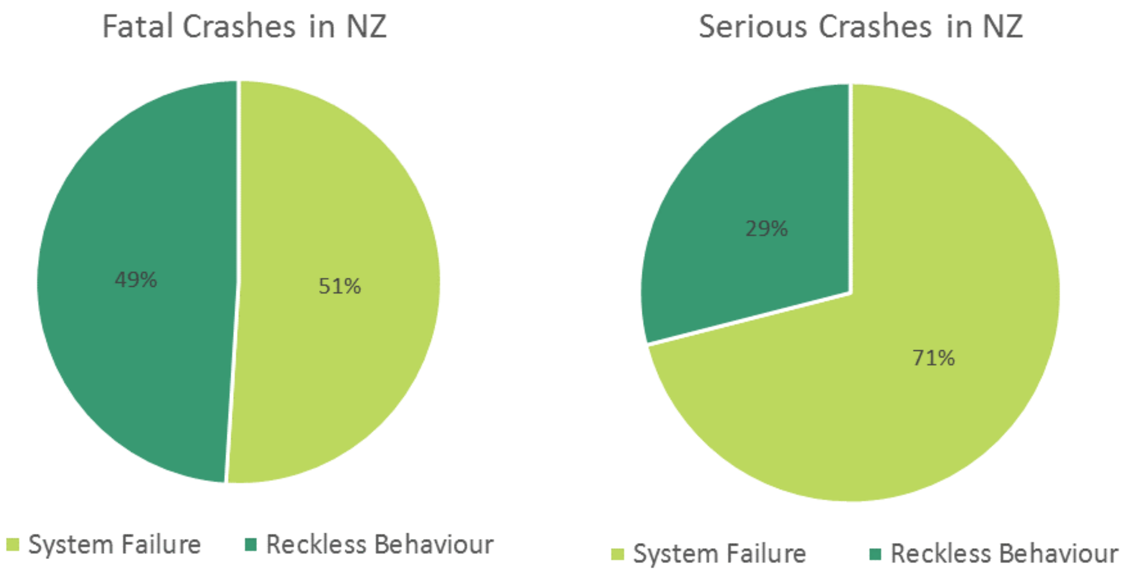


Figure 8. Proportion of fatal and serious crashes involving reckless behaviour



5. Discussion and Conclusions

A key finding from this analysis is that crashes often happen as a result of multiple system failures, further supporting the importance of the Safe System approach in road safety. Given that a large proportion of fatal crashes exhibited failures by all pillars of the safe system, road safety efforts should be rigorous in addressing all four pillars.

Often, it was clear that a minor driver lapse resulted in serious or fatal outcomes. This is in conflict with the Safe System approach which explains that although people make mistakes, the consequences for those mistakes should not result in their death or serious injury. In many cases, when a user lapse occurred, no ‘safety net’ was provided from any of the other safe system pillars (e.g. vehicle airbags, frangilbe road side objects, or a speed limit safe and appropriate for the conditions of the road). More effort could be given to identifying the pillar ‘safety net’ that is in place for various high-risk potential crash situations.

The analysis also showed that a high proportion of fatal crashes involved reckless behaviours with often multiple ‘unsafe acts’ being committed. It seems unlikely that conventional approaches to road safety will effectively address these situations and more work might be needed to identify these risky individuals or situations, taking a multi-agency approach.

There are a number of limitations with this research. The analysis is limited by the information available in crash reports and associated information sources. Nevertheless, we did find that for most crash cases, the information available provided a reasonable understanding of the system pillars that were likely to have played a part in each crash. The uncertainty was more related to the extent to which each pillar was critical in the crash. Also, the scope of work was deliberately limited to light vehicle crashes. Further similar work could be carried out for other road-user groups as needed.

Acknowledgements

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