Should We Treat Fatal and Injury Crashes Differently for Road Safety Treatment Selection? The Evidence says Sometimes Yes Sometimes No

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Abstract

Two opposing views exist regarding use of fatal versus injury crashes to guide selection of road safety treatment: (1) fatal and injury crashes are equally important in guiding road engineering treatments: (2) fatal crashes should be assigned more weight than injury crashes in determining treatment priorities. Each view is adopted into policy in various countries and programs. To date the debate on which view is correct has been theoretical with proponents arguing that fatal and injury crashes do or do not differ systematically in ways relevant to road design and engineering. For example, it is argued that other factors such as age and frailty of the victims, or safety afforded by their vehicle may determine whether the crash is fatal or injury, not the specific details of the crash or the road. The critical issue is whether fatal crashes predict that other crashes (of the same type at the same location) are more severe than if no fatality has occurred (at that location and crash type). This paper empirically informs this critical debate by testing this the predictive power of fatal versus injury crashes at crash cluster locations in South Australia. Extraordinarily, each view is correct in certain crash circumstances: fatal crashes predict more severe injuries in some circumstances (e.g. sideswipe crashes in <50kmh zone) but not others (e.g. rear-end crashes in <50km/h zone, or right-angle crashes in 70-80kmh zone). These results can be applied to improve use of fatal crashes in selecting and prioritising treatments to improve safety benefits.

Introduction

Road safety resources are finite, and thus the targeting of these resources to best road safety effect is demanded by Government, public sector management, and road safety stakeholders. This paper examines the extent to which resources may or may not be better targeted by treating fatalities and serious injuries differentially in analyses designed to select future road safety interventions. It may appear to some that the answer is obvious and thus it may be surprising that this is an issue for investigation. However, clearly dichotomous views regarding the interpretation of deaths versus injuries currently dictate road safety treatment prioritizations for various programs.

View 1: Fatal and injury crashes should be prioritised equally

The first view acknowledges that fatality and injury are, of course, radically different outcomes for those involved and for the economy, but contends that fatal and injury crashes are equally important indicators of treatment selection or prioritization. This is based on the belief that whether crashes result in deaths or injuries is not systematically and consistently related to the nature or location of the crash. Rather, in otherwise similar crashes in terms of the type of crash and location of the crash, people die due to extraneous factors (e.g. physical frailty, older cars, emergency response time). Thus, there is little value in separating fatalities from serious injury crashes for predicting future crashes and outcomes.

In addition, it is argued that the severity of the crash may be largely related to behaviours known to influence the risk of death versus injury in the event of a crash, such as whether a helmet (WHO, 2006) or seat belt was worn (Cummings, Wells & Rivara, 2003; Evans, 1996), or speeding (for reviews see Job & Sakashita, 2016, Nilsson, 2004). These may be seen as largely independent of the engineering of the location and thus severity should not be considered in decisions about road engineering solutions (such as black spot treatments). Although this is not correct for speeding, which can be managed through road design (Job & Sakashita, 2016), it is largely correct for seat belt and helmet use.

Finally, proponents argue that a focus on fatalities may be counterproductive because it results in a concentration on crash locations based on relatively rare events and there are many more injuries than serious deaths. Combining deaths and serious injuries (or injuries generally) results in a larger sample of cases on which to base decisions.

These beliefs result in treating fatal crashes and injury crashes equally for the selection of road safety works. This view dictates decisions in, for example, Australia's Federal Blackspot Program, which allows that blackspots are selected on the basis of total casualties combined regardless of the severity of the injury (fatality or non-fatal injury).

View 2: Fatal crashes should be prioritised over injury crashes

The second view is that fatal and injury crashes are systematically different. This is based on the belief that fatal crashes are not only more severe and costly as an outcome, but also even for the same crash type and location, systematic differences exist in the crash which results in a death versus an injury. The factors which caused the greater severity of outcome may be systematically related to the location. For example, whether the crash results in a death versus an injury is determined by speed of impact based on evidence that speed of impact dramatically influence survivability (Nilsson, 2004; WHO, 2008), and the design of locations vary in the extent to which they encourage versus manage speeding. In addition, off road crashes will vary in severity of outcome based on the objects struck, which vary from location to location. Furthermore, behavioural factors may be systematically related to the crash location (e.g. speeding and non-use of seat belts are more common on more remote rural roads where enforcement is less likely: Raftery & Wundersitz, 2011). Thus locations with fatal crashes versus injury crashes are systematically different in terms of risk of severe crashes.

Under these beliefs, greater weighting is given to fatal than injury crashes in prioritising safety treatments. This view dictates decisions in, for example, blackspot selection in Sweden (SweRoads, 2001).

The Importance of examining which view is correct

These views are both currently applied in road safety practice. The influence of these views on road safety policy is substantial. As noted above the Australian federal blackspots programs adopts the first view while the blackspot program in Sweden as adopts the second view. In addition, the governments of different states and territories of Australia and other countries have adopted different views regarding how to select locations for speed cameras and for red light cameras. Some have prioritised fatalities over injuries in determining locations while others have based locations on total severe casualties (deaths and injuries combined). To the extent that one of these views is correct and the other view is presumed in policy decisions, sub-optimal prioritisation of road safety resources is occurring. Thus, determining which view is correct will allow more effective prioritisation to provide maximum benefits from limited road safety resources.

To date the debate regarding these issues has occurred at a theoretical level: with arguments presented for the contributions to deaths which are extraneous to the engineering and design of the location (such as frailty of the victim) versus factors which are related to the engineering and design of the location (such as object struck or speed of impact). This paper offers an empirical method for determining which view is correct and applies that method to data form South Australia. Results will inform future blackspot methodology and influence strategies for enforcement and related communication campaigns on whether to treat fatal and injury crashes similarly or differently.

To the best of our knowledge, no published studies have examined specifically whether crash sites with fatalities predict more severe injuries than comparable (i.e. controlling for predictors of crash severity including crash type, speed limit and road features) crash sites without fatalities. However, studies undertaken for other purposes provide hints as to the answer. For example, a large scale study by the NSW Centre for road Safety comparing crash severities on curves of different radii across many roads in NSW revealed relevant results (Job, 2010). The results (Figure 1) show that property damage only (two away) crashes peak in frequency at curves of radii around 150m, while injury crashes peak around 250m yet fatal crashes peak around 400m radius curves. These data suggest that there are systematic difference in the locations of fatal and injury crashes.

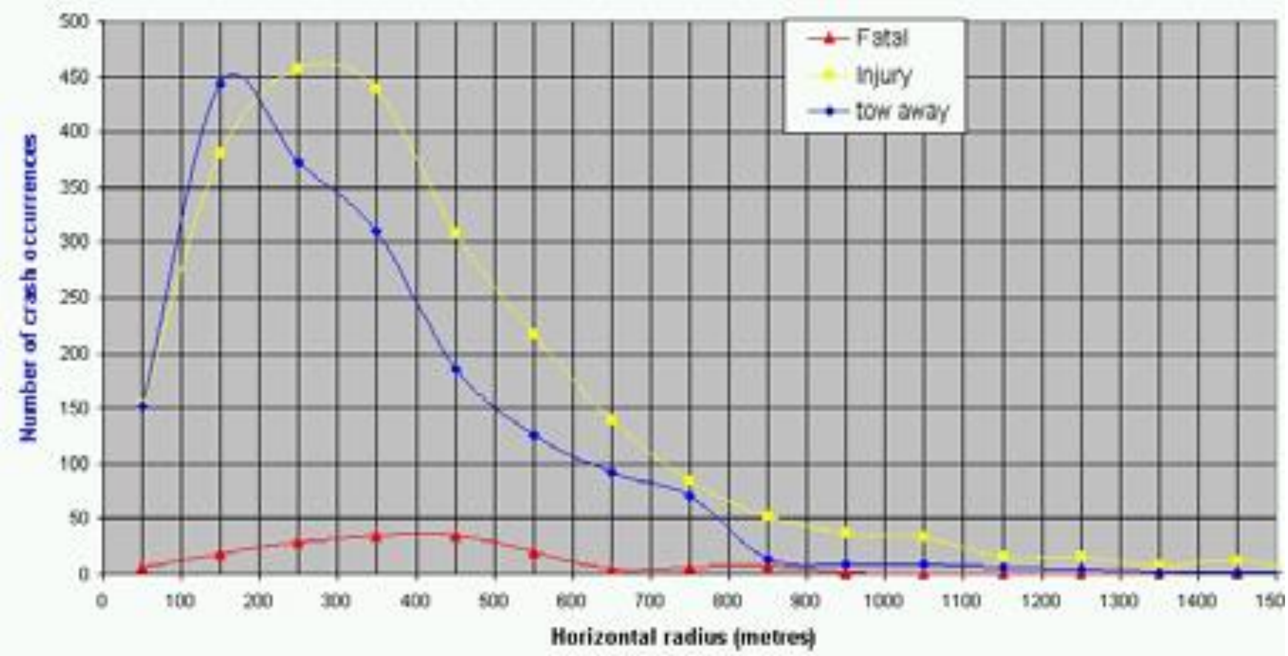

Figure 1: Frequencies of tow-away, injury and fatal crashes across curves of different radii (Job 2012)

Rationale for the Present Research

The dichotomous views on the treatment of fatalities and injuries in determining road safety interventions have been debated largely on the basis of the factors contributing to deaths in crashes (frailty versus location related factors, etc.) as described above. One way to empirically resolve this critical debate is to examine the extent to which fatal versus injury crashes differentially predict severity of other crashes (controlling for various additional factors). After all, this is the real issue determining how we should use fatal and injury crashes to select and prioritise road safety treatments: If the presence of fatal crashes predict more severe other crashes than the presence of injury crashes then fatal crashes should be given greater weighting in treatment prioritisation. On the other hand, if fatal and injury crashes are equal in predicting the severity of other crashes, then they should be employed equally in prioritising road safety treatments. Once seen this way, the debate can be addressed through the following specific research question: Do crash locations and crash types with fatalities have more severe injuries than otherwise similar crash locations and crash types where injuries but no fatalities have occurred? To take a concrete example, we can examine all instances of clusters of rear-end collisions at signalised intersections in 60km/h zones. We then classify the locations of all such crashes as being those where a fatal rear-end collision has occurred (called fatality-present locations) versus those where injury but not fatal crashes have occurred (called fatality-absent locations). We then compare the severity of injury crashes at these two sets of locations. The above described two views make explicit opposing predictions of the outcome. The view that fatal versus injury outcomes are determined by factors extraneous to the location (frailty, safety of the vehicle) predicts that the presence of a fatal crash versus only injury crashes makes no systematic difference in predicting the level of severity of other crashes at the relevant locations. The second view, that fatal versus injury outcomes are determined by factors related to the location (design, object near the road) predicts that fatal present location are likely to be higher risk and so injury crashes at these locations will be more severe.

Methods

Study 1: In order to answer this research question, the analyses were conducted employing crash and Compulsory Third Party (CTP) claims data from 1 January 2000 to 30 June 2013 in South Australia. Figure 2 presents a scheme of how the data were employed. Claims cost data (with discounts for at fault behaviour such as drink-driving reversed so that the claim cost is more reflective of injury) were employed as an admittedly imperfect measure of injury severity. Some limitations include: 1) claims costs vary with evolving medical treatments and their costs; 2) variability of schemes also means costs are not comparable across jurisdictions, rendering precise benchmarking and control comparisons for evaluation purposes impossible. However, a separate study using the same data sources has demonstrated validity of claims cost as a proxy measure for injury severity where claim costs were found to have increasing positive relationship with low, medium, and high injury severity injury (CDSU 2015a). Moreover, claim costs are influenced by all the factors of the crash which influence severity and the issue herein is whether within those factors there is a significant amount of variance attributable to factors predicted by fatal versus injury crash at comparable locations.

CTP claim amounts awarded per injury at intersections where a fatality had occurred were compared with the CTP claim amounts awarded per injury at intersections where no fatality had occurred, with intersections matched on crash type, speed zone, and traffic control. Study 1 was restricted to intersections to allow for clusters of crashes at comparable locations. Ratios of claim costs at fatality-present locations to claim costs of fatality-absent locations were computed. A ratio of 1 indicates that the costs of injuries at fatality-present and fatality-absent locations are the same, ratios above 1 indicate that injuries cost more at fatality-present locations and ratios below 1 indicate that injuries cost less at fatality-present locations. T-tests were also conducted to examine if the mean costs at fatality-present versus and fatality-absent locations were statistically significant (defined at p-value of 0.05).

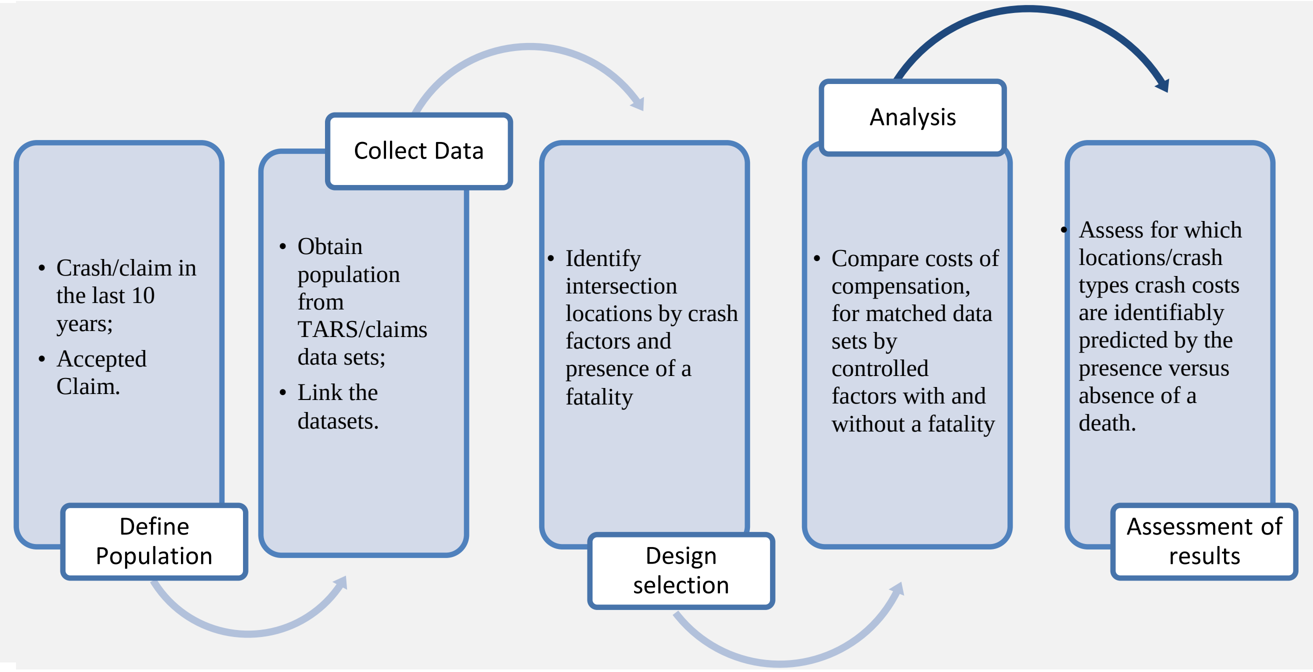

Figure 2: Schematic of injury data examination (CDSU 2015b)

In order to control other extraneous contributors to crash severity, crashes which involved especially severe vehicles or especially vulnerable vehicles were excluded Study 1: trucks and busses, motorcycles, bicycles, and pedestrians.

Study 1 control for crash type (6 types included, as presented in Table 1) intersection control (5 levels, as presented in Table 1) and speed limit (4 levels as in Table 1, with some limits excluded due to small sample size) means that this study may be interpreted as comprising 120 sub-studies (6 x 5 x 4) of parallel form. However, many of these comparisons contained too few cases, and results were not analysed, leaving 42 sub-studies with usable results.

Study 2: While pedestrian crashes were excluded from Study 1, because they occur particularly at intersections allowing sufficient data on these crashes, pedestrian crashes were treated separately, in Study 2. The rational and form of analysis were the same as in Study 1, except that there was only one crash type: pedestrian crash.

Results

Study 1 results controlling for factors of speed limit, intersection traffic control and crash type at once are provided in Table 1 including sample size for each comparison as well results. Study 2 results are reported in Table 2 (pedestrian crashes only).

For ease of scanning, fatality-present to fatality-absent ratios above 1.5 are in bold. Ratios between 0.95 and 1.05 are in italics. Ratios below 0.5 are in bold italics. Ratios above 1.5 suggest that injury costs at fatality-present locations are over 50% greater than injury costs at fatality-absent locations, which can be considered practically significant difference. Ratios between 0.95 and 1.05 suggest that injury costs at fatality-present versus fatality-absent locations differ within around 5%, which can be considered not to be a difference of little practical significance. Ratios below 0.5 suggest that injury costs at fatality-present locations are more than 50% less than injury costs at fatality-absent locations, which can be considered practically significant difference, though in an unexpected direction. All other ratios (i.e. above 1.05 and less than 1.5; greater than 0.5 and below 0.95) suggest that injury costs between fatality-present and fatality-absent locations are less than 50%. Further research for these crash circumstances may be required before making a judgement on the practical significance of these differences.

Statistical significance tests were performed on the ratios to further verify the differences. All of the ratios above 1.5 and below 0.5 were statistically significant, confirming their statistical reliability as well as practical significance. Two crash circumstances with a ratio between 0.95 and 1.05 were statistically significant (rear end and right turn crashes at traffic controlled intersections in 60km/h speed zone). However, the other two crash circumstances with ratios between 0.95 and 1.05 were statistically non-significant (right angle crashes at intersections with give way sign in 70-80km/h speed zone and right angle crashes at intersections with stop sign in 90-100km/h speed zone). Statistical significant is possible in cases of small practical impact when the sample size affords high statistical power.

Table 1. Study 1 summary results: comparisons of claims costs of injuries at fatality-present and fatality-absent locations controlling for speed limit, intersection controls, and crash type and statistical significance of the fatality-present to fatality-absent ratios

Speed limit	Traffic Control	Crash Type	Number of Claims (Fatality-absent locations)	Average Claim Cost (Fatality-absent locations)	Number of Claims (Fatality-present locations)	Average Claim Cost (Fatality-present locations)	Fatality-present to fatality-absent ratio	Significance of the difference between fatality present and fatality absent locations
50 km/h or below	Traffic Signals	Rear End	193	40,209	26	30,780	0.77	significant
50 km/h or below	No Control	Rear End	96	33,821	10	13,719	***0.41***	significant
50 km/h or below	Traffic Signals	Right Turn	105	36,270	17	24,293	0.67	significant
50 km/h or below	Traffic Signals	Right Angle	90	58,871	6	97,906	**1.66**	significant
50 km/h or below	Traffic Signals	Side Swipe	8	9,203	6	122,168	**13.27**	significant
60 km/h	Roundabout	Rear End	189	35,263	12	61,865	**1.75**	significant
60 km/h	Traffic Signals	Rear End	2,067	35,355	498	36,354	*1.03*	significant
60 km/h	Stop Sign	Rear End	178	27,029	12	45,809	**1.69**	significant
60 km/h	No Control	Rear End	1,115	42,325	42	24,850	0.59	significant
60 km/h	Traffic Signals	Right Turn	1,886	45,926	553	44,516	*0.97*	significant
60 km/h	Give Way Sign	Right Turn	68	27,724	9	60,194	**2.17**	significant

60 km/h	No Control	Right Turn	384	42,370	24	70,353	**1.66**	significant
60 km/h	Traffic Signals	Right Angle	764	48,735	138	52,147	1.07	significant
60 km/h	Stop Sign	Right Angle	489	41,817	44	78,503	**1.88**	significant
60 km/h	Give Way Sign	Right Angle	367	34,196	21	103,365	**3.02**	significant
60 km/h	No Control	Right Angle	969	43,883	41	123,689	**2.82**	significant
60 km/h	Roundabout	Side Swipe	16	23,246	6	102,246	**4.4**	significant
60 km/h	Traffic Signals	Side Swipe	66	38,479	25	50,947	1.32	significant
60 km/h	No Control	Side Swipe	44	45,030	7	179,964	**4.0**	significant
60 km/h	Traffic Signals	Head On	32	74,701	13	46,440	0.62	significant
60 km/h	No Control	Head On	53	47,450	6	62,470	1.32	significant
60 km/h	Traffic Signals	Hit Fixed Object	50	33,465	10	312,878	**9.35**	significant
60 km/h	Stop Sign	Hit Fixed Object	14	22,295	13	145,528	**6.53**	significant
60 km/h	No Control	Hit Fixed Object	45	91,031	18	153,617	**1.69**	significant
70-80 km/h	Traffic Signals	Rear End	383	38,790	107	46,854	1.21	significant
70-80 km/h	Stop Sign	Rear End	14	38,396	5	33,647	0.88	non-significant
70-80 km/h	No Control	Rear End	92	49,033	8	25,281	0.52	significant
70-80 km/h	Traffic Signals	Right Turn	257	70,003	87	44,497	0.64	significant
70-80 km/h	Stop Sign	Right Turn	7	40,985	9	113,957	**2.78**	significant
70-80 km/h	No Control	Right Turn	82	80,999	18	68,683	0.85	significant
70-80 km/h	Traffic Signals	Right Angle	133	49,642	29	63,293	1.27	significant
70-80 km/h	Stop Sign	Right Angle	89	54,247	23	77,626	1.43	significant
70-80 km/h	Give Way Sign	Right Angle	94	65,732	28	66,011	*1.0*	non-significant
70-80 km/h	No Control	Right Angle	173	45,869	27	96,079	**2.09**	significant

90-100 km/h	Traffic Signals	Rear End	7	16,640	12	95,062	**5.71**	significant
90-100 km/h	No Control	Rear End	31	39,059	10	42,752	1.09	non-significant
90-100 km/h	No Control	Right Turn	33	51,839	13	112,801	**2.18**	significant
90-100 km/h	Stop Sign	Right Angle	27	63,994	23	62,699	*0.98*	non-significant
90-100 km/h	Give Way Sign	Right Angle	46	49,919	44	88,160	**1.77**	significant

Note: Some combinations are missing because at least one of the cells for fatality-present or fatality-absent locations contained less than 5 cases, which is too few cases to provide reliable results; Ratios >1.5 are in bold; Ratios between 0.95 and 1.05 are in italics.

Table 2. Study 2 summary results: comparisons of claims costs of injuries at fatality-present and fatality-absent locations controlling for speed limit, intersection controls, and crash type and statistical significance of the fatality-present to fatality-absent ratios for Hit Pedestrian Crashes only

SPEED LIMIT	Traffic Controls	Number of Claims (Fatality-absent locations)	Average Claim Cost (Fatality-absent locations)	Number of Claims (Fatality-present locations)	Average Claim Cost (Fatality-present locations	Fatality-present to fatality-absent ratio	Significance of the difference between fatality present and fatality absent locations
50 km/h or below	No Control	33	88,312	5	72,256	0.82	non-significant
60 km/h	No Control	124	83,498	11	562,817	**6.74**	significant
60 km/h	Traffic Signals	211	75,718	37	65,698	0.87	significant

Note: Ratios >1.5 are in bold.

Discussion

The overall results of Study 1 present an extraordinary picture. Both views under consideration appear to be correct in particular circumstances. Of the 42 ratios computed, 27 were statistically significant and above 1. Of the 27 ratios above 1, 20 were above 1.5 and ranged between 1.66 and 13.27. That is, in 48% of the crash circumstances examined, injury costs at fatality-present locations were between 66% and 1327% greater than injury costs at fatality-absent locations, clearly supporting View 2, that fatal and injury crashes should be treated differently in prioritising safety treatments.

However, in four crash circumstances, the ratios were very close to 1 (including 0.98 and 1.00) and non-significant, indicating that there is no systematic difference in the severity of crashes at fatality-present versus fatality-absent locations. These ratios can be treated as indicating that the fatal crashes offer no practical prediction of severity of crashes beyond that offered by injury crashes. These cases support View 1.

Even more extraordinarily, there are clear and statistically significant circumstances where a fatal crash predicts the exact opposite. Of the 42 ratios computed, 10 were statistically significant and below 1. Of the 10 ratios below 1, only one ratio was below 0.5, at 0.41. This was for rear-end crashes at no traffic control intersection in 50km/h or below speed zone. In this crash circumstance, injury costs are almost 60% less at fatality-present locations than at fatality-absent locations. These cases support neither view, and the ratio of .42 is difficult to understand. (Speculative explanations are possible in terms of locations in high income areas, with safer cars, less dangerous behaviours but occasional fatalities due to older (retired) people living in wealthy area.)

Study 2 also produced mixed results even though sufficient sample size for statistical analysis only existed in 3 sub-studies. Unsurprising these were in urban speed zones. The significant result supported View 2, with injuries at fatality-present locations costing over 6.5 times injuries at fatality-absent locations. Study 2 may also be limited by the use of all pedestrian crashes due to available detail, whereas pedestrian crashes involve many types (walking from the opposite or near side of the road, emerging from behind a vehicle, walking along the road versus crossing, etc.).

The most obvious account of the broad range of results is simply that they represent random variation, due to the use of multiple tests or claim cost data which do not fully reflect injury severity. While the claim cost data are influenced by factors other than severity, injury severity is a major factor in cost. In addition, for a number of statistical reasons, random variation can be dismissed as an account. These effects are genuine, and in most instances of a size which is practically relevant. Thus, they demand explanation. Random variations may became statistically significant because many statistical tests were undertaken and .05 tests will be significant by chance. Of the 45 statistical test undertaken, at .05 probability we would expect 2 false positive results, whereas only 6 of the 45 tests over studies 1 and 2 were not significant. This is well beyond chance rate, indicating a legitimate though unexpected set of results. Finally, the results are not randomly distributed across crash types and speed zones. For example, rear end crashes and right turn crashes each have 4 instances of statistically significant results where fatalities predict lower claims costs, whereas hit fixed object and right angle crashes have none.

Conclusions

These results may be applied to identify which crashes should be assigned a higher weighting for fatal crash locations and for what crashes we should not in order to maximise the impacts of treatments. Based on this new evidence, there are some intersection types and crash types for which we should weight fatal crashes higher than injury crashes, and others for which there is no systematic difference and the crashes can be equally weighted, to increase the precisions of targeting of road safety engineering and behaviour changes interventions.

The present study may open the door to a range of additional investigations to comprehensively address this important issue of crash data usage. Extension of this work to non-intersection crashes and to a more comprehensive set of pedestrian crash types will be of value, to provide a more complete commentary on the circumstances in which fatalities should be and should not be given additional weighting.

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