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The Relationship between Speed and Car Driver Injury Severity

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EXECUTIVE SUMMARY

The relationship between speed and injury severity was explored for seat-belted car drivers in impacts with other cars. The results were compared to a recent paper by Wramborg (2005), which also presented the relationship between speed and injury severity. Information on fatally and seriously injured drivers from the Co-operative Crash Injury Study (CCIS) and slightly injured drivers from the On the Spot (OTS) study were combined. The number of fatal, serious and slightly injured drivers in this dataset were weighted using the police STATS19 database, and the risk of injury with respect to the change of velocity of the driver's car was calculated.

1 DATA SOURCES

This report uses the findings from two of the UK's in-depth real world accident investigation projects, the Co-operative Crash Injury Study (CCIS) and the On the Spot (OTS) project. Accident investigations undertaken from 2000 to the present were included and involved all makes, models and ages of cars. Both datasets have a common methodology for assessing impact severity, called delta-v, which is the change of velocity of the vehicle. The calculation of delta-v requires detailed measurements of the vehicles' residual crush and a forensic investigation of the damage to mathematically reproduce the impact configuration. The appropriate vehicle stiffness parameters are then applied and, where robust information is available, the delta-v is calculated. Analysis of this measure of 'speed' (Lenard *et al.*, 1998; Cookson *et al.*, 2008) has shown that delta-v is accurate to approximately $\pm 10\%$.

1.1 Co-operative Crash Injury Study

The Co-operative Crash Injury Study (CCIS) is an ongoing project which has collected in-depth real world crash data since 1983. Vehicle examinations are undertaken at recovery garages several days after the collision. Car occupant injury information is collected and questionnaires are sent to survivors. Accidents are investigated according to a stratified sampling procedure, which favours cars containing fatal or seriously injured occupants as defined by the British Government's definitions of fatal, serious and slight. More information on the data collection methods employed can be found at www.ukccis.org.

The data from CCIS used included details of 64 fatally injured belted drivers in frontal impacts with another car; 463 seriously injured belted drivers in frontal impacts with another car; 21 fatally injured drivers in side impacts with another car (on the struck side); and 75 seriously injured belted drivers in side impacts with another car (on the struck side).

1.2 On the Spot

The On the Spot (OTS) study began in 2000 and is funded by the Department for Transport and the Highways Agency. It aims to establish an in-depth database that can be used to improve the understanding of the causes and consequences of road traffic accidents, and thus aid the Government in reducing road casualties.

There are two OTS teams: the Transport Research Laboratory (TRL) covers the Thames Valley area, and the Vehicle Safety Research Centre (VSRC), attached to Loughborough University, covers Nottinghamshire. Expert investigators from these teams attend the scenes of accidents, usually within 15 minutes of an incident occurring, using dedicated response vehicles and equipment. In total, the teams

make in-depth investigations of about 500 crashes per year, and record in excess of 2,000 pieces of information about each accident.

In contrast to other accident studies which are based on evidence gathered after incidents, or based on secondary evidence, OTS investigations allow 'perishable' accident data to be gathered. These include trace marks on the highway, pedestrian contact marks on vehicles, the final resting places of the vehicles involved, the weather at the time of the incident, visibility and traffic conditions. Medical data and questionnaires are also collected. Full details of the methodology of OTS are given in Cuerden *et al.* (2008).

The data from OTS included details of 76 slightly injured car drivers in frontal impacts with another car, and 21 slightly injured car drivers in side impacts with another car (on the struck side).

1.3 STATS19

STATS19 is the national database in which all traffic accidents that result in injury to at least one person are recorded, although it is acknowledged that some injury accidents are missing from the database and some non-injury accidents are included. The database primarily records information on where the accident took place, when the accident occurred, the conditions at the time and the location of the accident, details of the vehicles involved, and information about the casualties. Over 60 pieces of information are collected for each accident.

STATS19 was used to determine the average number of car driver casualties in front and side impacts (on the struck side) from 2005–07, by injury severity. These figures were used to weight the results from CCIS and OTS.

2 METHOD

The speed–injury curves were created using a combination of data from the Co-operative Crash Injury Study (CCIS) and the On the Spot (OTS) study, and weighting this to represent the number of casualties recorded in STATS19. Injury curves were created for two groups of road casualties: car drivers in a car which experienced a frontal impact with another car, and car drivers in a car which sustained a side impact with another car, where the driver was seated on the struck side.

For the car drivers, the data for the speed curves was obtained from CCIS for fatal and seriously injured casualties and from OTS for slightly injured casualties. The slight casualties from OTS were used because this database is more representative of the accident population. The CCIS database, because of its sampling procedure, tends to record the more ‘serious’ slightly injured occupants. In part this is related to the tow-away inclusion criteria: in other words, the car damage and/or driver injury necessitated that the car be towed by a recovery agent. However, CCIS is believed to be representative of killed and seriously injured accidents, so this was used for the killed and serious casualties because of the greater sample size.

The measure of speed used to draw the speed–injury curves for the car drivers was the change of velocity, or delta- v , of their vehicles. Delta- v is defined as the difference between the vehicle’s immediate pre-impact and post-impact velocity. The immediate post-impact velocity depends on the relative velocity of the vehicles involved, the mass of the vehicles, their stiffness, and the direction of the impact. Delta- v is a better predictor of injury than other measures of speed, such as the impact speed or closing speed.

The speed–injury curves for fatal injury and killed or serious injury (KSI) were fitted using logistic regression (Pallant, 2005). This process predicts how a variable with only two possible values (in this case ‘fatal’ or ‘not fatal’, and ‘KSI’ or ‘not KSI’) is dependent on a continuous variable (in this case delta- v). Confidence intervals were also drawn, which show the area within which the true speed–injury curve could actually lie, given limitations in the data, for example the size of the sample. These curves were produced using a combination of the statistical packages SPSS and R. This process also allowed the data to be weighted, so that the results would better reflect the national accident population. The data were weighted to the number of casualties in STATS19. The weighting process is summarised in Tables 2.1 and 2.2 for car drivers in frontal impacts and car drivers in side impacts, respectively.

Table 2.1: Calculating weighting factors for car drivers in frontal impacts with other cars				
Injury severity	Sample from CCIS/OTS	Sample in STATS19	Seat-belt wearing rates (%)	Weighting factors
Fatal	64	479	73	5.46
Serious	463	6,744	83	12.1
Slight	76	81,642	89	955

Table 2.2: Calculating weighting factors for car drivers in side impacts with other cars				
Injury severity	Sample from CCIS/OTS	Sample in STATS19	Seat-belt wearing rates (%)	Weighting factors
Fatal	21	119	80	4.53
Serious	75	1,275	91	15.5
Slight	21	24,141	94	1,080

It should be noted that the seat-belt wearing rates were estimated using the information present in CCIS. This was needed because only belted drivers were included in the CCIS sample, therefore the number of casualties in STATS19 needed to be reduced by the proportion which were not wearing seat belts.

The purpose of the speed–injury curves is to estimate the probability of fatal or serious injury in an accident at different impact speeds for different impact types. These will be compared with those curves produced by Wramborg (2005), which are shown in Figures 2.1 and 2.2. These show the probability of fatality for a car occupant in a front impact and a car occupant in a side impact.

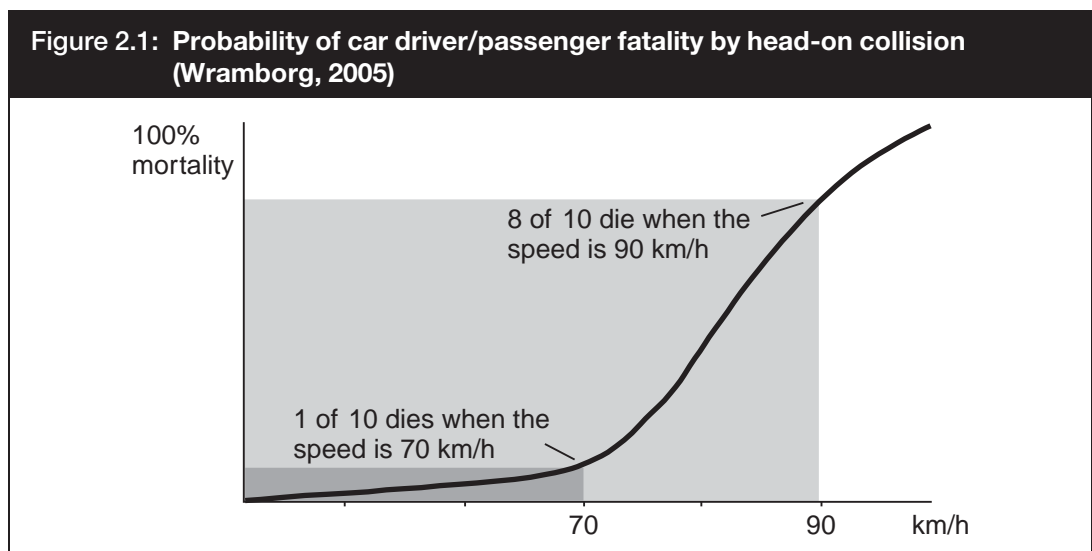
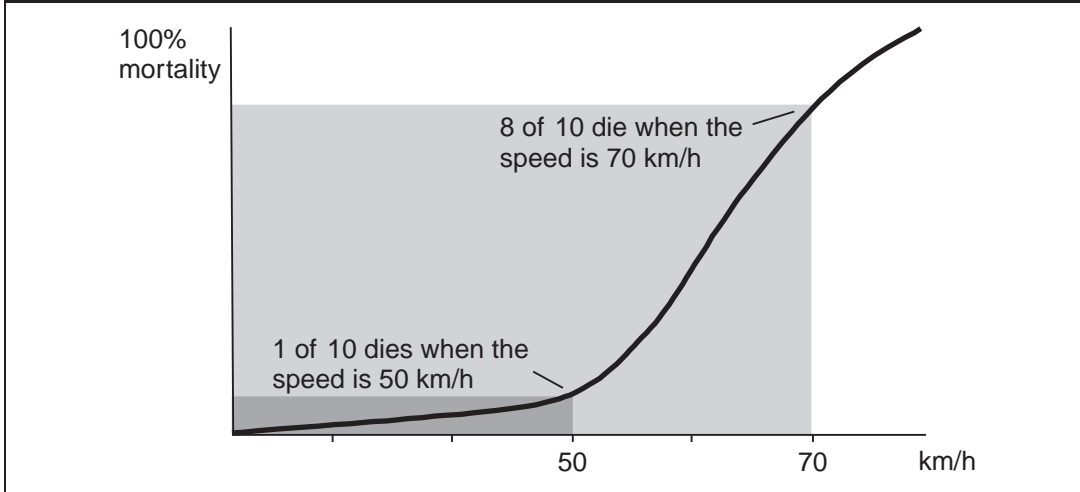


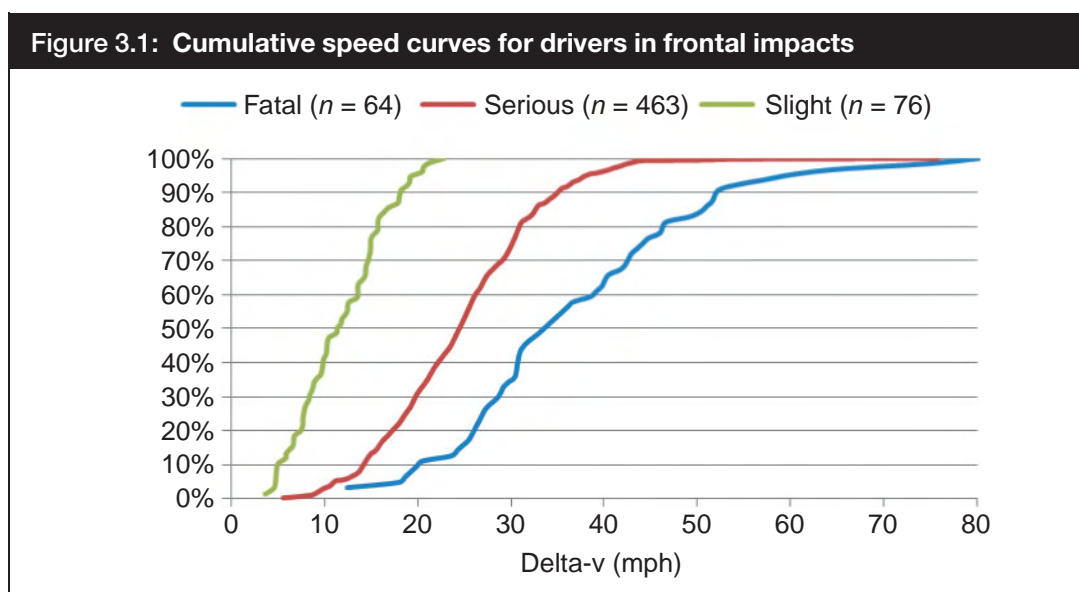
Figure 2.2: Probability of car driver/passenger fatality by side impact collision (Wrangborg, 2005)



3 RESULTS

3.1 Frontal impacts

Figure 3.1 shows the cumulative speed (delta-v) distribution of seat-belted drivers in frontal impacts who were fatally, seriously and slightly injured. The fatally and seriously injured drivers are from the Co-operative Crash Injury Study (CCIS) database, and the slightly injured drivers are from the On the Spot (OTS) database.



The relationship between higher speeds and more severe injury is clear in this graph. The 50th percentile speed for slightly injured drivers is 11 mph, for seriously injured drivers it is 24 mph and for fatally injured drivers it is 34 mph.


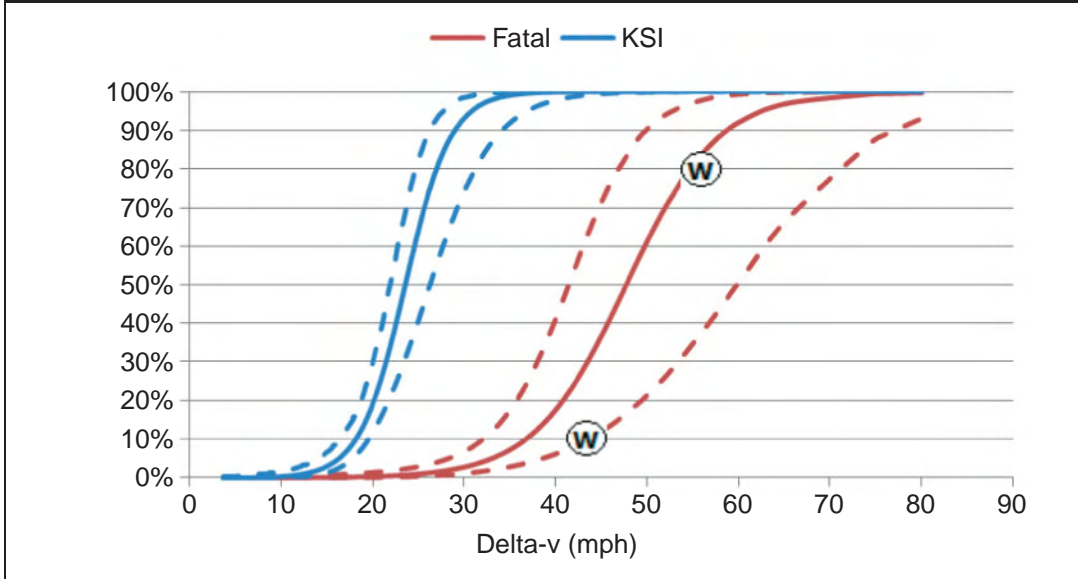
Figure 3.2 shows the speed–injury curves which were calculated for drivers of cars in frontal impacts with other cars. This shows the estimated percentage of drivers who would be killed or seriously injured (KSI) or killed in an impact of a given delta-v. The dashed lines around each curve give the confidence intervals for that curve. This figure also shows the risk of fatality given by Wramborg (2005), shown by the  symbol.

Figure 3.2 estimates that 3% of drivers would be killed in frontal impacts with a delta-v of 30 mph, 19% would be killed at 40 mph, 65% would be killed at 50 mph, and 92% would be killed at 60 mph. The risk figures quoted by Wramborg (2005) are within the confidence intervals shown in Figure 3.2. However, it is not known what method Wramborg has used to measure speed. If Wramborg did not use delta-v as the speed measure, the results will not be directly comparable.

Figure 3.2: Speed injury risk curve for car drivers in frontal impacts with other cars

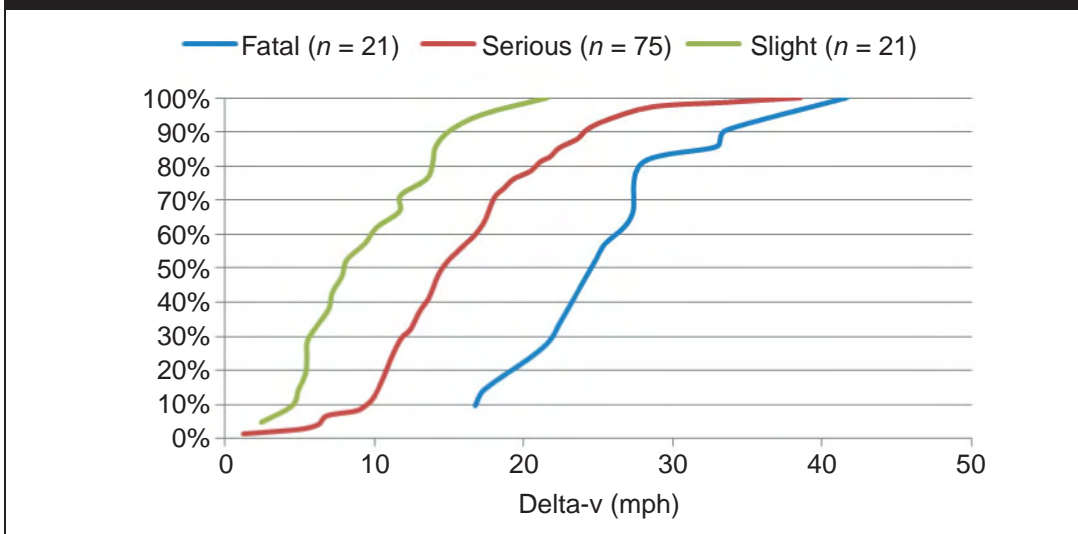


The confidence intervals around the KSI line are relatively small. This reflects the relatively large size of this dataset, which contains details of 527 KSI car drivers in frontal impacts with other cars.

3.2 Side impacts

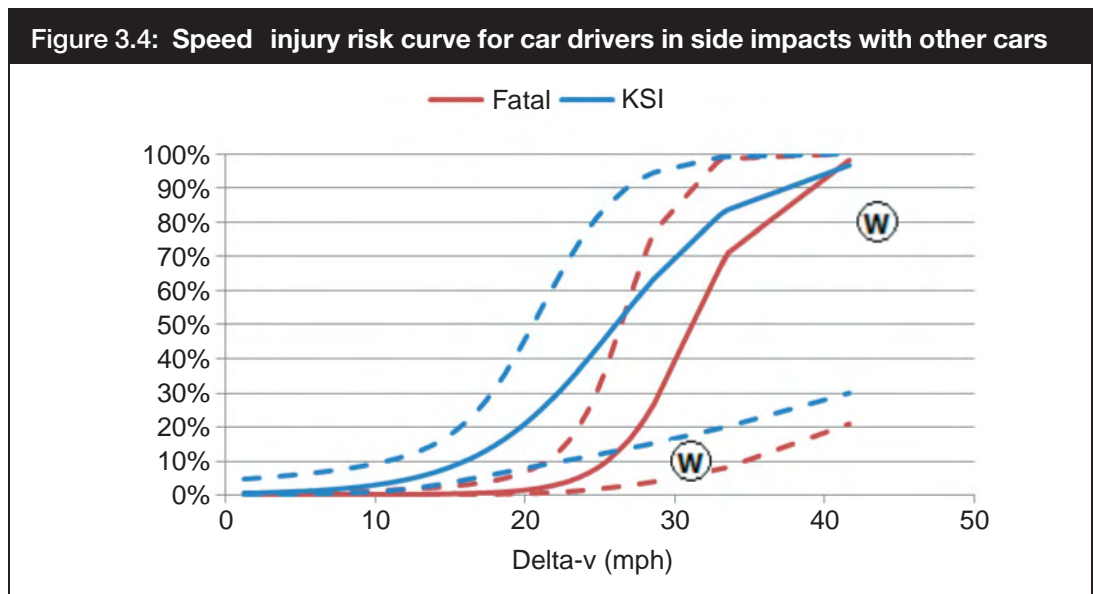
Figure 3.3 shows the cumulative speed (delta-v) distribution of drivers in side impacts with another car who were seat belted and on the struck side of the car. The fatally and seriously injured drivers are from the CCIS database, and the slightly injured drivers are from the OTS database.

Figure 3.3: Cumulative speed curves for drivers in side impacts



Again, the relationship between higher speeds and increased injury severity is clear. The 50th percentile delta-v for slightly injured drivers is 8 mph, for seriously injured drivers it is 15 mph, and for fatally injured drivers it is 24 mph. This sample size is much smaller than the sample size for frontal impacts: approximately 73% smaller for slightly injured drivers, 84% smaller for seriously injured drivers, and 68% smaller for fatally injured drivers. In the national accident population (Tables 2.1 and 2.2), the number of slight injuries in side impacts is 70% smaller than the number of slight injuries in frontal impacts, 81% smaller for serious, and 75% smaller for fatally injured drivers.

Figure 3.4 shows the speed–injury curves calculated for drivers in side impacts with another car.



This figure estimates that approximately 40% of drivers would be killed in a side impact with a delta-v of 30 mph, and 90% of drivers would be killed in a side impact with a delta-v of 40 mph. However, it should be noted that the confidence intervals on both the fatal and KSI curves are relatively wide. This is due to the relatively small number of side impacts, with other cars, where delta-v was known: a sample of 117 people of all severities.

4 DISCUSSION

From the cumulative speed graphs, the relationship between delta-v and injury severity seems clear: there is a clear difference in the distribution of speeds for slight, serious and fatally injured drivers in both frontal and side impacts. However, although these graphs show that speed is a factor, there are obviously many other factors which affect the injury severity of car drivers in these impacts. For example, for car drivers in frontal impacts with a delta-v of 12–20 mph, there were drivers who were slightly, seriously and fatally injured. Although the effect of seat-belt use has been accounted for, there are many other variables which are likely to have an effect on the injury severity. These include, but are not limited to:

- the age and gender of the driver;
- the exact location and type of impact;
- the relative seating position of the driver;
- the size, shape and stiffness of the vehicles involved;
- the presence of airbags and other restraint systems; and
- the amount of time before emergency medical attention could be given.

The graphs showing the risk of injury with delta-v account for these differences by estimating the probability of the driver being killed or seriously injured, or fatally injured. However, the width of the confidence intervals are affected by the spread of the data, i.e. the variation in injury severity for crashes at the same speed. As this variation is relatively large, the number of cases required to give narrow confidence intervals is also relatively large. For example, the curve showing the risk of KSI in a frontal impact is created from a sample of over 500 cases (before weighting to STATS19), and so the confidence intervals on this curve are relatively narrow. However, the curve showing the risk of KSI in a side impact is created from around 100 cases (before weighting), so the confidence intervals on this curve are relatively wide.

When Wramborg's (2005) findings are compared to these risk curves, they are within the confidence intervals; however, in general, Wramborg's findings are not close to the line of best fit. It should be noted that, at the current time, relatively little is known about Wramborg's findings. It is unknown whether he used delta-v, or some other measure of speed (such as impact speed). It is also unknown whether the car occupants in his sample wore seat belts. The age distribution of the vehicles in his sample and the impact partners of the cars are also unknown. Any differences such as these between Wramborg's sample and the sample used in this report would make comparison of the two results difficult.

To improve the confidence intervals, especially for the side-impact curves, requires a larger number of cases than is currently available. The number of cases could be increased in a number of ways, but most of these would also affect the shape of the curves and their validity. For example, the number of criteria on the samples could be reduced, such as including all drivers regardless of belt use, including drivers who were not on the struck side of the vehicle, and including impacts with large vehicles and stationary objects as well as cars. This would increase the size of the sample and reduce the size of the confidence intervals, but would mean that the figures would not relate to a particular type of accident, rather they would be an average for all types of accident.

One of the most important factors which determine the size of the confidence intervals in these risk curves is the number of slightly injured drivers. These have currently been taken from the On the Spot (OTS) study, as this has a more representative sample of slightly injured casualties than is present in the Co-operative Crash Injury Study (CCIS). However, the number of car driver casualties in OTS is small compared with CCIS, and is weighted to a large number using STATS19 (for example, the number of slightly injured drivers in side impacts in OTS is 21, which is weighted to 24,141 using STATS19). Using the slight casualties from CCIS would give a larger sample, and may improve the confidence intervals significantly; however, it is known that the slight casualties in CCIS tend to occur at higher speeds (delta-v) than in OTS, so the results would be less representative of the national casualty population.

Finally, it should be noted that these risk curves give the risk of KSI or fatal injury, **given that the driver is at least slightly injured**. No details of drivers who were in an impact and who were not injured have been included in the calculations to create these graphs. The likely effect of this is that the risk of KSI and fatality will be overestimated at lower speeds, perhaps less than about 15 mph.

5 CONCLUSIONS

Speed curves have been created for seat-belted drivers in front and side impacts, which give the risk of KSI and fatal injury by the change in velocity (delta-v) of that vehicle. These have been created using casualties recorded in the Co-operative Crash Injury Study (CCIS) for fatal and serious casualties, and the On the Spot (OTS) study for slightly injured casualties.

For belted drivers in front impacts with another car, the risk of fatality is calculated as 50% at a delta-v of 48 mph, and the risk of killed or seriously injured (KSI) is calculated as 50% at a delta-v of 24 mph.

For belted drivers on the struck side in side impacts with another car, the risk of fatality is calculated as 50% at a delta-v of 31 mph, and the risk of KSI is calculated as 50% at a delta-v of 26 mph.

The confidence intervals on some of these curves are relatively wide, especially for the side-impact curves. This is because of the relatively small sample containing all the information required, such as delta-v. The confidence intervals are also widened by the relatively small number of slight injuries included in the analysis. The slight injuries were included from the OTS study because it is more representative of slightly injured casualties than CCIS.

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