A REVIEW OF THE EUROPEAN 40% OFFSET FRONTAL IMPACT TEST CONFIGURATION

Richard Cuerden
Rebecca Cookson
Phillip Massie
Mervyn Edwards
TRL Limited (Transport Research Laboratory)
United Kingdom
Paper Number 07-0318

ASTRACT

Frontal impacts are the most frequent crash type and account for the majority of Killed and Seriously Injured (KSI) car occupant casualties in Europe. This study reviews the performance of modern cars (registered in 1996 or later) in frontal impacts, which are most associated with KSI casualties. Comparison is made with the 40% offset legislative (UNECE R94) and consumer (EuroNCAP) tests. The aim of the study is to evaluate how well the 40% offset configuration and the associated vehicle loading and intrusion factors represents the real life injury experience sustained in frontal impacts.

Co-operative Crash Injury Study (CCIS) data collected from June 1998 has been used. There were 806 KSI seat belted casualties who experienced frontal impacts and were occupants of cars registered in 1996 or later. The majority of these victims were drivers. The study then analyses 435 drivers who had impacts that involved direct contact to the front right corner of the car. The nature of the vehicle loading in terms of structural features is considered and compared with the injury outcome and the associated mechanisms. Car to car impacts are the most common, although larger goods and passenger vehicles are prominent among crash partners in fatal crashes. About 80% of the fatalities are encompassed by the EuroNCAP frontal test speed rising to 95% of the seriously injured survivors.

More than half of the KSI car occupants sustain their injuries in impacts with more than 40% overlap and a significant proportion of these crashes involve direct loading to both longitudinals. Thoracic injuries caused by seat belt loading and lower extremity injuries caused by facia and footwell contact are the main body regions injured. Approximately 80% of the MAIS=2 and 50% of the MAIS 3+ injury is sustained by survivors with little or no intrusion to the compartment (<10cm).

INTRODUCTION

Over the past ten years frontal impact crashworthiness has significantly improved with the advancement of car structures and restraint systems. The European frontal impact directive (UNECE R94) and EuroNCAP tests continue to promote the enhancement of crash energy management structures, aimed at reducing the amount of loading occupants experience.

The EuroNCAP frontal impact test is based on the European legislation, but is conducted at a higher impact speed. The car strikes a 40% offset deformable barrier head-on at 64kph. The 40% offset is a percentage measure of the car's width. The test requirements have resulted in an increase in compartment strength and, as a consequence, intrusion is less common in real-life frontal impacts (Edwards, 2007). Over the same period, developments in airbag and seat belt restraint system technologies have reduced the likelihood of head contacts with the interior of the vehicle during a frontal impact (Cuerden, 2001). Correctly restrained occupants' head and facial injuries have been significantly mitigated. However, frontal impacts are still the most frequent crash type and account for the majority of Killed and Seriously Injured (KSI) car occupant casualties in Europe.

This paper outlines the characteristics of relatively modern cars (registered in 1996 or later) in frontal impacts, which are most associated with KSI casualties. Comparison is made with the 40% offset legislative and consumer tests.

The data source is the UK's Co-operative Crash Injury Study (CCIS), which is one of Europe's largest car occupant injury causation studies (www.ukccis.org). The programme of research started in 1983 and continues to investigate real-life car accidents. Multi-disciplinary teams examine crashed vehicles and correlate their findings with the injuries the victims suffered to determine how car occupants are injured. The objective of the study is to improve car crash performance by continuing to develop a scientific knowledge base, which is used to identify the future priorities for vehicle safety design as changes take place.

The study carefully selects accidents to be representative of injury car crashes that occur in the UK and is a good data source to undertake an in-depth review of the characteristics of frontal crashes that result in KSI car occupant casualties.

METHOD

Co-operative Crash Injury Study

The Co-operative Crash Injury Study investigates and interprets real-world car occupant injury crashes retrospectively. Police reported injury road traffic crashes from defined geographical areas of England are reviewed to establish if they meet the CCIS sample criteria. The basic selection criteria used for the accidents presented in this analysis were:

- The accident must have occurred within the investigating teams geographical area
- The vehicle must be a car or car derivative
- The vehicle must have been less than 7 years old at the time of the accident
- The vehicle must have at least one occupant who is injured (according to the police)
- The vehicle must have been towed from the scene of the accident.

The CCIS case or accident injury severity is based on the most severe injury to an occupant of a car less than 7 years old and therefore may be lower than the police reported accident severity. Accidents were investigated according to a stratified sampling procedure, which favoured cars that met the age criteria and contained a fatal or seriously injured occupant as defined by the British Government definitions of fatal, serious and slight. Where possible all crashes that met the criteria and involved a CCIS classified fatal or seriously injured occupant were investigated. Random selections of accidents involving slight injury were also investigated, up to a target maximum.

Vehicle examinations were undertaken at recovery garages several days after the collision. An extensive investigation of the cars' residual damage and structural loading along with detailed descriptions of the restraint system characteristics and any occupant contact evidence was recorded using the CCIS data collection protocols. This process allows the nature and severity of the impact(s) and/ or rollover damage to be precisely documented so different crash types can be compared.

Car occupant injury information was collected from hospital records, coroners' reports and questionnaires sent to survivors. The casualties' injuries were coded using the Abbreviated Injury Scale (AIS, AAAM 1990 Revision). AIS is a threat-to-life scale and every injury is assigned a score, ranging from 1 (minor, e.g. bruise) to 6 (currently untreatable). The Maximum AIS injury a casualty sustains is termed MAIS. The scale is not linear; for example, an AIS 4 is much more severe than two AIS scores of 2.

Table 1.
AIS Score Categories

AIS Score	Description
0	No Injury
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum
9	Unknown

The casualties' characteristics (age, gender, seat belt use) and injury information were correlated with the vehicle investigation evidence. This methodology allows the causes and mechanisms of the injuries to be documented.

The crash severity parameter used for this study is the car's change of velocity (Delta-V).

Accidents investigated between June 1998 and March 2006 are included in the analysis (CCIS Phases 6, 7 and 8 – to data release 8a).

Car Occupant Casualties in Great Britain

In the UK, STATS19 accident forms are completed for all injury road traffic crashes. The information recorded captures the details of all road users, but compared to in-depth studies such as CCIS, provides only an overview of the event. However, the first point of contact on the vehicle is identified by the investigating police officer. This may not be the principal or most severe impact, but it is a good estimate as to the nature and respective importance of the different crash types.

Five years of STATS19 data were analysed (1999 to 2003) and car occupant casualties selected. On average in this period there were 1,723 fatalities and 19,106 KSI car occupant casualties per year. The front was described as the first point of impact on the car for 50% (853 occupants) of the killed and 58% (11,041) of the KSI casualties, emphasising the relative importance of this crash type.

In Great Britain in 2004 (RCGB 2004) there were 11,885 under 16 year olds and 167,797 people aged 16 years or older reported as injured car occupant casualties. Proportionally, there are far more under 16 year olds seated in the rear of the car (Figure 1). Rear passengers represent a little over 10% of all car occupant casualties.

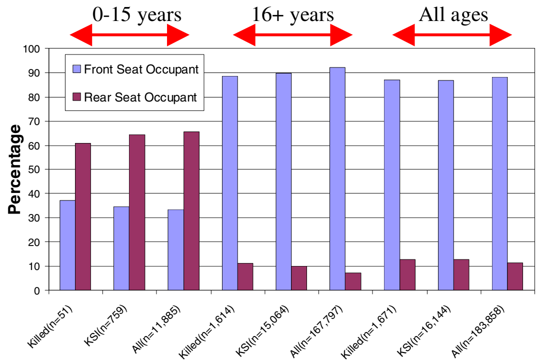

Figure 1. Car Occupant Casualties by Seating Position (RCGB 2004)

The casualties' seat belt use is not recorded in STATS19 and so CCIS was analysed to estimate the relative usage rates by seating position and gender. Figure 2 shows that drivers are most likely to be belted, followed by Front and Rear Seat Passengers (FSP and RSP). Females in all seating positions used their seat belts more frequently. Seat belt use decreased with increasing occupant injury severity. Figure 2 shows that 29% of the male and 16% of the female drivers were unbelted and fatally injured. Approximately 70% of the male and 56% of the female RSPs were unbelted and fatally injured. Occupant age is also a significant factor when seat belt use is investigated.

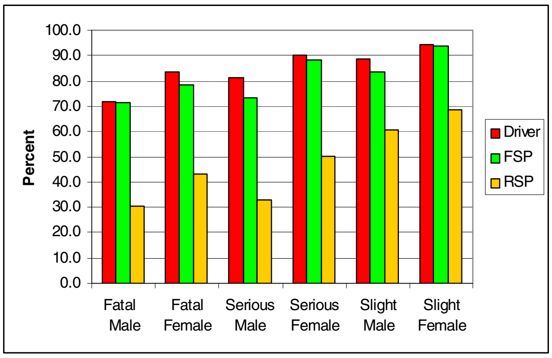

Figure 2. Seat belt use rate by Injury Severity, Gender and Seating Position

Car seat belts are very effective safety devices, reducing the risk of serious and fatal injury. It is often assumed that seat belt performance in crashes is the same for all seating positions, and yet there are good and obvious reasons why that is not the case. The surrounding physical environment and the seat belt and airbag technologies differ between the seating positions. The driver, front and rear seat passenger populations are very different with respect to gender and age. These different occupant characteristics and seat belt use rates are observed by road-side surveys and recorded casualties (Figure 2). Only seat belted occupants were considered for this analysis and so a large percentage of rear seat passengers were excluded. Similarly, a significant number of male serious casualties and a proportion of the fatalities were excluded due to the seat belt criteria.

The CCIS database is far better at describing crash types with respect both to the chronological order of the impacts and to the extent of the measured damage compared with STATS19. Further, occupant characteristics such as seat belt use are routinely recorded unlike in STATS19. Finally, the use of AIS as a descriptor ensures a more precise definition of the injury severity compared with 'serious', which covers most injury outcome from minor fractures to death more than 30 days after the crash. However, the CCIS database is not fully representative of the national car occupant crash population and there are some limitations to this study.

CCIS Occupant Selection

There were 1,652 MAIS 2+ seat belted casualties who were occupants of cars registered in 1996 or later. The injury severity classifications used for this paper are grouped as:

- MAIS = 2, Moderate
- MAIS 3+, Serious, Survivors
- Killed

Approximately half of the selected casualties sustained MAIS 2 injury. All ages were included; some 12 children were secured on or by child restraints. To explore the relative importance of frontal impacts, occupants were differentiated by their crash type.

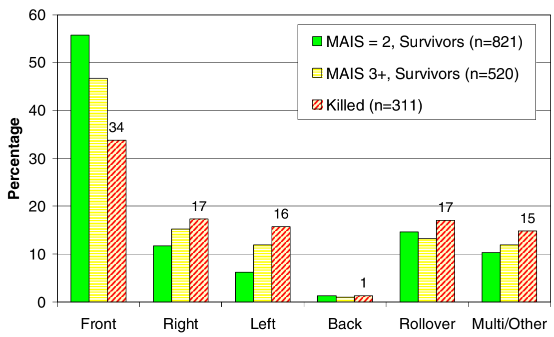

Figure 3. Crash Type by Injury Severity for Seat Belted MAIS 2+ Car Occupants

Figure 1 shows the relative importance of frontal impacts compared with the other main crash types and identifies the level of injury suffered respectively. The crash types were classified by the principal impact location on the car. If there were two or more significant impacts to different sides of the vehicle, each causing more than 10cm of crush, these vehicles are grouped as 'Multi/other' crash type. Any car that rolled over, with or without an impact, either before, after or during the roll, are classified as 'Rollover' crash type.

For all MAIS 2+ casualties frontal impacts represent nearly half of the crash types. As the injury severity increases other crash types become proportionally more common, but frontal crashes are still the most frequent. Eight hundred and six casualties who had experienced frontal impacts with no rollover or other significant impacts were selected.

Casualties with a MAIS 2 or greater were selected for this study to represent police reported KSI casualties. It is recognised that this is not an exact match. Approximately 38% of the CCIS casualties described by the police as serious were classified as MAIS 0 or 1. Approximately 9% of the CCIS casualties described by the police as slight were classified as MAIS 2+. Therefore in general the selection criteria bias the analysis to occupants who sustained specific and more severe injury than that suffered by the average 'serious' car occupant casualty population in Great Britain. Nonetheless, for the ease of analysis, the MAIS 2+ category provides a useful estimate. Some serious injury is not directly related to impact trauma, such as shock, and this research excludes non-injury based outcomes and concentrates on the identification of specific and severe injuries that are sustained by car occupants in modern vehicles as a result of frontal impacts.

RESULTS

Table 2 shows the injury severity by seating positions for the 806 selected casualties who experienced a frontal impact. Approximately 70% of the occupants were drivers. Males accounted for roughly 62%, 25% and 35% of the drivers, FSPs and RSPs respectively. Tables 3 to 5 indicate that the distribution of casualty age is different with respect to seating position; generally FSPs were older and RSPs younger than the drivers. When the crash severity (Delta-V) is known, drivers are typically found to experience higher values for the same injury level compared with passengers.

Table 2.
Occupants by Position and Injury Group

Seating Position	Injury Group			Total
	MAIS=2	MAIS 3+	Killed	
Driver	310	183	74	567
FSP	126	42	25	193
RSP	22	18	6	46
Total	458	243	105	806

Table 3.
Summary of Driver Characteristics

	MAIS = 2 (n=310)	MAIS 3+ (n=183)	Killed (n=74)
Age 25%ile	31 years	26 years	31 years
Age 50%ile	45 years	42 years	49 years
Age 75%ile	57 years	56 years	65 years
% Male	59.4%	63.9%	68.9%
With known DV N=	*156*	*114*	*36*
DV 25%ile	29 kph	37 kph	47 kph
DV 50%ile	37 kph	45 kph	54 kph
DV 75%ile	44 kph	53 kph	65 kph
% hit a car	68.6 %	60.1 %	47.3 %
% hit larger vehicle	19.1%	27.3%	40.5%

Table 4.
Summary of Front Passenger Characteristics

	MAIS = 2 (n=126)	MAIS 3+ (n=42)	Killed (n=25)
Age 25%ile	30 years	20 years	29 years
Age 50%ile	44 years	52 years	56 years
Age 75%ile	63 years	65 years	74 years
% Male	22.2 %	28.6 %	36.0 %
With known DV N=	*65*	*23*	*16*
DV 25%ile	24 kph	30 kph	30 kph
DV 50%ile	33 kph	39 kph	37 kph
DV 75%ile	44 kph	48 kph	49 kph
% hit a car	71.8 %	66.7 %	48.0 %
% hit larger vehicle	12.9 %	26.2 %	36.0 %

With respect to the object hit there is some variation, but it was most commonly found to be another car or a larger vehicle. The small RSP sample is due both to the low occupancy rates for this seating position and the low seat belt use rates.

Table 5.
Summary of Rear Passenger Characteristics

		MAIS = 2 (n=22)	MAIS 3+ (n=18)	Killed (n=6)
Age	25%ile	11 years	13 years	-
	50%ile	17 years	17 years	31 years
	75%ile	53 years	23 years	-
% Male		27.3 %	38.9 %	50.0 %
With known DV N=		*14*	*12*	*3*
DV	25%ile	24 kph	30 kph	-
	50%ile	31 kph	42 kph	58 kph
	75%ile	48 kph	49 kph	
% hit a car		59.1 %	61.1 %	50.0 %
% hit larger vehicle		9.1 %	11.1 %	50.0 %

The 806 casualties' frontal impacts are summarised in Figures 4 to 8 with respect to the loading and severity of damage to the car's structure. Although each crash is individual, the following representation of the data attempts to group and compare the similarities found in each scenario. Figure 4 shows that the majority of frontal impact MAIS 2+ casualties were in collisions with other cars. Crashes with heavier vehicles (HGVs - including large passenger service vehicles) were far less common, but accounted for some 30% of the fatalities. It is worth noting the small number of crashes that occurred with roadside objects (narrow and wide).

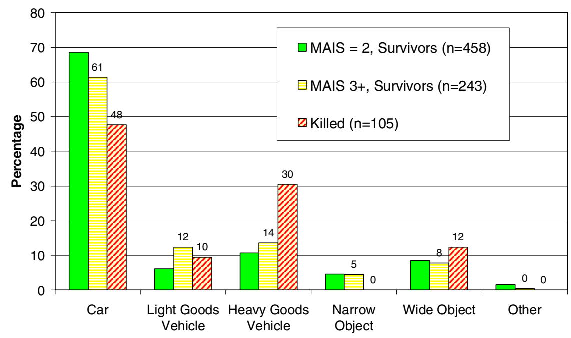

Figure 4. Object Hit by Car Occupant Injury Severity

The crash severity parameter used for this study is Delta-V (DV) or the Change of Velocity measured in kph. This is calculated based on the amount of residual crush the impact partners experienced. It is not always possible to determine a Delta-V for a variety of reasons associated with the manner in which the vehicle was loaded and the characteristics of the impact partner. However, of the 806 MAIS 2+ occupants, 438 (54%) had a Delta-V and are shown in Figure 5. Differentiating between the different injury severity groups and considering the 80th percentile, we find that the Delta-Vs for MAIS=2, MAIS 3+ (Survived) and Killed were 47kph, 54kph and 64kph respectively. Note that, when Delta-V is known there is a bias towards more survivable crashes with other cars; it is often not possible to calculate a crash severity measure for massive impacts and/or impacts with larger vehicles where the stiff structures have been over-run.

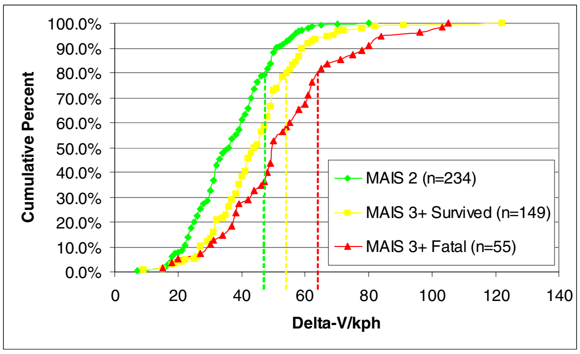

Figure 5. Distribution of Delta-V by Injury Severity

Figures 6 and 7 describe the frontal impact characteristics in more detail. CCIS uses the Collision Deformation Classification (CDC) to describe the damage cars sustain. Two variables within the code are used in this study, the Principal Direction of Force (PDF) of the impact and the specific location of the direct contact damage on the car (Figure 7 details the key for the coding letters).

Approximately 75% of the occupants experienced a PDF that was head-on (0°±15°) (Figure 6).

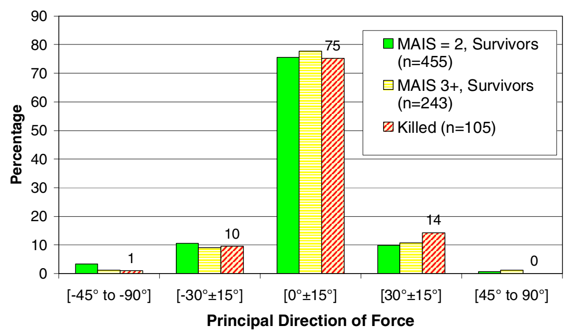

Figure 6. PDF by Car Occupant Injury Severity

Figure 8 is based on all PDFs. The most common loading location for MAIS 2+ casualties involved more than 66% direct contact (code D - 66-100% of car's width). However, it is not possible to compare this directly with the 40% offset configuration used in legislative and consumer tests, as not all the impacts will have involved loading to a front corner of the vehicle. In addition, the position and percentage overlap of the direct loading with respect to the side the occupant is seated can be an important factor, in terms of the amount of intrusion and/or rotational accelerations experienced. In Figures 4 to 8 all seating positions have been considered and consequently there is a bias towards drivers.

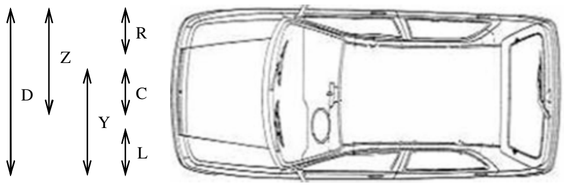

Figure 7. CDC Part Code, Direct Damage Location

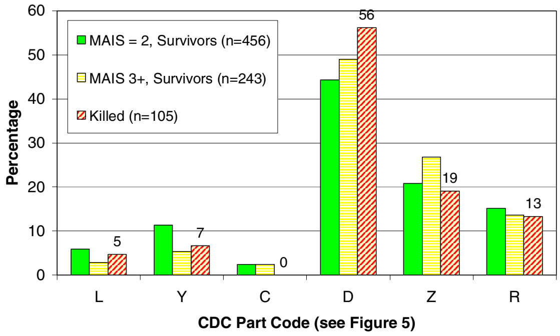

Figure 8. Direct Damage Location by Car Occupant Injury Severity

Body Regions Injured

The occupants were divided by seating position and the relative rate of injury to their different body regions by severity is given in Figures 9 to 11, for drivers, front and rear seat passengers. The percentage plotted for each body region is calculated as the proportion of occupants with an injury to a body region of the same AIS level as their injury grouping. For example, there were 310 drivers classified as MAIS = 2, some 115 of these drivers had an AIS 2 thorax injury or 37% (115/310). The AIS 3, 4, 5 and 6 injuries are all grouped as AIS 3+.

The relative frequency of injury to the body regions varies with respect to the seating position; this is related both to the different occupant characteristics in terms of age and gender associated with each seating position; and the different protection afforded to each seating position in terms of seat belt and airbag technologies. It is often assumed that seat belt performance in crashes is the same for all seating positions, and yet there are good and obvious reasons why that is not the case. In the front of a car, the instrument panel or facia is contacted by the knees in most front impacts where the velocity change exceeds 30kph. Airbags are now standard features for front impact protection and supplement the seat belt performance. This means that in higher energy front crashes a substantial proportion of an occupant's energy is transferred through these knee and airbag contacts, reducing seat belt loads. The kinematics of the restrained rear seat occupant are different as there are no equivalent limiting knee or airbag contacts. The backs of the front seats are much more compliant and deformable; hence the rear seat belts have to manage proportionally more of the crash energy. It is therefore a more challenging condition from the point of view of rear seat restraint design. A particular concern is the potential for rear seat occupants to submarine under the lap portion of the seat belt webbing, causing the abdomen to be loaded.

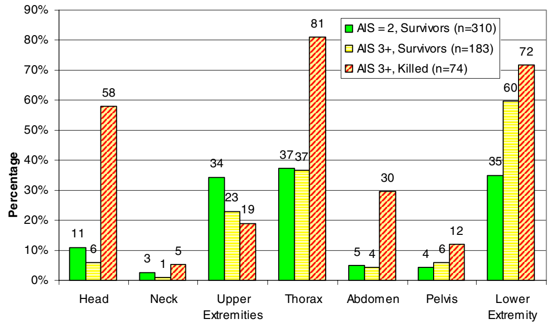

Figure 9. Injury Regions for Drivers

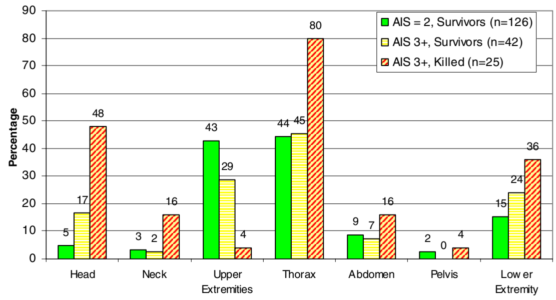

Figure 10. Injury Regions for Front Seat Passengers

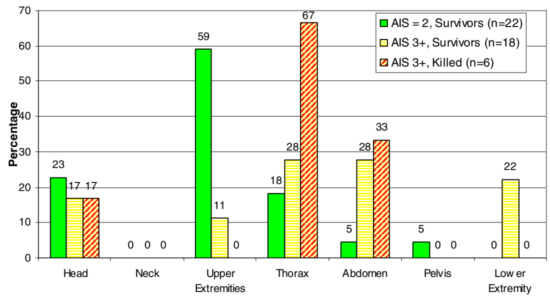

Figure 11. Injury Regions for All Rear Seat Passengers

For MAIS = 2 and MAIS 3+ survivors, abdomen injury was relatively uncommon for drivers and front passengers. However, 28% of the MAIS 3+

rear passengers sustained an AIS 3 or greater abdomen injury. The sample size is small and more detailed investigation is required to fully understand the mechanism that resulted in these injuries and to determine if more modern seat belt designs would have mitigated them or reduced their severity.

For MAIS = 2 casualties, the most commonly injured body regions at AIS = 2, for drivers were the thorax (37%), lower (35%) and upper (34%) extremities. For FSPs the order changed and the rate of injury observed was different with injuries to the thorax (44%), upper (43%) and lower (15%) extremities. The largest difference was observed for the RSP, with the upper extremities (59%), the head (23%) and the thorax (18%) being most commonly injured.

For MAIS 3+ survivor casualties, the most commonly AIS 3+ injured body regions, for drivers were the lower extremities (60%), the thorax (37%) and the upper extremities (23%). For FSPs the order changed and the rate of injury observed was different with injuries to the thorax (45%), upper (29%) and lower (24%) extremities. The largest difference was observed for the RSPs, with the thorax (28%), the abdomen (28%), the lower extremity (22%) and the head (17%) being most commonly injured.

For those casualties who were killed, the most common body regions injured at AIS 3+ were the thorax and head for the drivers and FSPs and the thorax and abdomen for RSPs.

For those drivers and front passengers who sustained a thorax injury, the nature of the injury is further outlined in Table 6. Specifically, injuries were evaluated as to be either, Skeletal, Internal or a combination of the two. The most common injury type was skeletal only (28%), followed by skeletal and internal (14%) and internal only (4%).

Table 6.
Nature of Drivers' and Front Seat Passengers' Thorax Injuries

Thorax Injury	MAIS = 2	MAIS 3+	Killed	Total
AIS 0	145	83	11	239
AIS 1	116	45	4	165
Skeletal only	175	27	11	213
Internal only	0	22	12	34
Skeletal and Internal	0	48	61	109
Total	436	225	99	760

Detailed Evaluation of the Cars' Front Loading and Overlap for Drivers

The direct impact loading to the front structural components of the cars was evaluated with respect to the drivers' injury outcome. Each car's front structure was simplified to comprise an offside (right or UK driver's side) longitudinal, a nearside longitudinal and an engine. The CCIS vehicle investigators record if these components were directly loaded in the crash and outline the extent of the crush and/or bending. For this paper, a simple matrix has been established to outline which combinations of structural loading most commonly occur for the injured drivers (MAIS 2+).

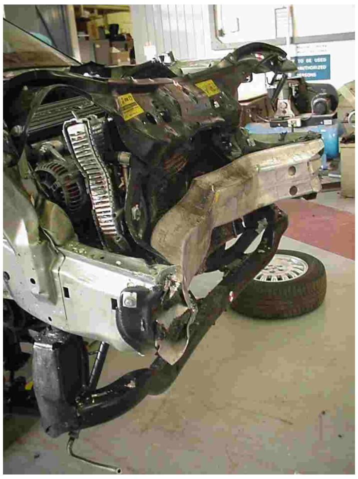

Figure 12. View of offside (right) longitudinal and engine compartment.

Table 7.
Directly loaded longitudinals and/or engine related to occupant injury severity

	MAIS = 2 (n=310)	MAIS 3+ (n=183)	Killed (n=74)	Total (n=567)
None loaded	10.32%	7.65%	5.41%	8.82%
Offside only	8.71%	6.01%	8.11%	7.76%
Nearside only	4.19%	1.09%	0.00%	2.65%
Offside and Nearside	5.48%	3.28%	2.70%	4.41%
Engine only	8.39%	5.46%	9.46%	7.58%
Offside and Engine	26.45%	37.16%	40.54%	31.75%
Nearside and Engine	11.29%	8.20%	2.70%	9.17%
All	24.52%	31.15%	29.73%	27.34%
One or more unknown	0.65%	0.00%	1.35%	0.53%
Total	100%	100%	100%	100%

Table 7 highlights that the offside longitudinal and the engine are the areas which are directly loaded together most commonly. The second most common configuration involves the offside and nearside longitudinals and the engine (All) being directly loaded. Some 31% of the drivers experienced loading to the offside and nearside longitudinals only or to 'All' three components. It is interesting to note that for the more seriously injured or killed drivers, the relative frequency of loading to the offside and engine or all three components increases.

To establish a more direct comparison with the current frontal impact legislation, cars were selected which had experienced direct contact to the front right corner or experienced 80% offset loading or greater. This yielded a sub-sample of 435 drivers, or 77% of all the drivers who met the original sample selection criteria. The selected drivers are summarised in Table 8. The broad characteristics of the sub-sample of 435 drivers were found to be very similar to those of the 567 drivers included in the early findings.

As with the original selection of drivers (567), significant differences were observed between the three injury groups; the sub-sample of drivers ages and Delta-Vs were found to increase ($p<0.05$) with the increasing injury severity.

Table 8.
Summary of Driver Characteristics with Right Front Corner Direct Contact Damage

	MAIS = 2 (n=225)	MAIS 3+ (n=146)	Killed (n=64)
Age 25%ile	31 years	27 years	32 years
Age 50%ile	44 years	42 years	50 years
Age 75%ile	57 years	56 years	68 years
% Male	60.9%	64.4%	70.3%
With known DV N=	*119*	*94*	*33*
DV 25%ile	30 kph	38 kph	47 kph
DV 50%ile	40 kph	46 kph	55 kph
DV 75%ile	45 kph	53 kph	66 kph
% hit a car	76%	65.8%	51.6%
% hit larger vehicle	17.8%	26.7%	40.6%

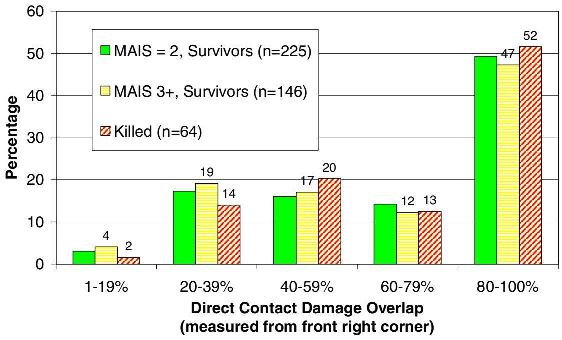

Figure 13. Percent Overlap by Driver Injury Severity

Figure 13 shows the distribution of injury severity by the percentage overlap; the injury severity is reasonably consistent within each of the offset groups, with similar proportions of MAIS =2 and MAIS 3+. Only about 36% of the killed and 40% of the MAIS 3+ survivors had an impact that was less than 60% offset.

The accuracy of the percentage overlap measured in the field is important to consider. Experienced examiners record the damage they find as accurately as practical, but it is possible for some small measurement errors to occur. A greater concern is the potential for retrospective studies to overestimate the amount of direct contact damage for cars that have rotated during the impact due to their angular momentum. When a car collides an extra degree of deformation may take place compared to the initial contact area due to rotation. This additional damage is sometimes difficult to differentiate from that caused at the initial point of contact.

This potential overestimation may affect the results of the degree of overlap shown in Figure 11 and underestimate the number of cars that are involved in impacts below 60% overlap. However, it is still believed that the most frequent type of impact has a greater overlap than the 40% used in either of the tests.

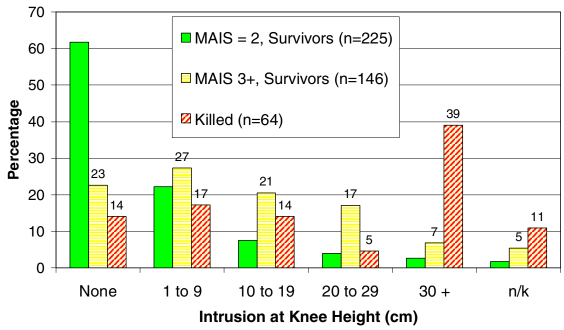

Figure 14. Facia Intrusion by Driver Injury Severity

Figure 14 shows the amount of intrusion rearwards into the compartment space at the driver's facia knee height level. Intrusion of the facia top and foot well were also considered and similar results to those shown in Figure 14 were observed. The percentage of MAIS 3+ survivors who experienced less than 10cm of intrusion at the facia top, facia knee height and foot well were 48%, 50% and 46% respectively. The percentage of killed drivers who experienced less than 10cm of intrusion at the facia top, facia knee height and foot well were 27%, 31% and 22% respectively. Significant intrusion is therefore much more common for killed drivers than for MAIS 3+ survivors, approximately half of whom experienced less than 10cm.

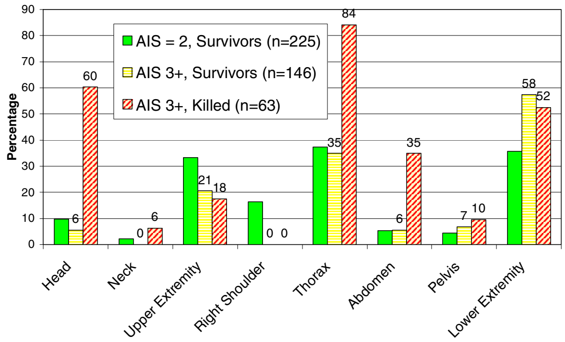

Figure 15. Rate of Driver Body Region Injury

Figure 15 shows the distribution of AIS=2 injuries by body region for the MAIS=2 group and the distribution of AIS 3+ injuries for the other two groups. One MAIS=2 driver who died was excluded from Figure 13; no Delta-V was known for this victim. AIS 3+ head and thoracic injuries are sustained much more frequently by the MAIS 3+ killed compared to the survivors. Thigh and leg injuries (lower extremities) are the most frequent AIS 3+ scores for the MAIS 3+ survivors. For the MAIS=2 drivers only, the rate of AIS 2 right shoulder injury was noted, with 16% of the casualties sustaining clavicle fractures or dislocations from seat belt webbing loading.

CONCLUSIONS

Significant numbers of fatal and rear seat passengers are excluded from this analysis due to low seat belt use rates.

The different occupant characteristics with respect to seating position are emphasised, and indicate that different dummies may potentially be required in each seat to best represent the real-world frontal impact injury population in future tests.

Frontal impacts remain the most significant crash type accounting for the majority of MAIS 2+ and MAIS 3+ car occupant casualties. Car to car impacts are the most common, although larger goods and passenger vehicles are prominent crash partners in fatal collisions.

About 80% of the fatalities (drivers and passengers) are encompassed at the EuroNCAP frontal test speed (64 kph) rising to 95% of MAIS 3+ seriously injured survivors.

Drivers, FSPs and RSPs were found to sustain injury to similar body regions, but the relative rates were different. Thorax, lower and upper extremity injuries were identified as frequently injured body regions for front occupants.

A detailed evaluation of the cars' front structural loading found that for all 567 MAIS 2+ drivers, the offside and nearside longitudinals were both directly contacted in approximately one third of cases (31%); and the engine was also loaded in the most of these crashes (27%). A further third of the MAIS 2+ drivers were in cars with direct contact to the offside longitudinal and engine (32%).

Evaluating the amount of car frontal direct contact damage by the percentage overlap recorded by the crash investigators, found similar results to those reported from the investigation of the structural component loading. More than half of the MAIS 2+ car drivers sustain their injuries in frontal impacts with more than 40% overlap. However, further analysis of the data would be required to determine the specific nature of these crashes in order to understand their significance with respect to current test configurations.

Compartment intrusion of ≥ 10cm is common for frontal crashes resulting in driver death, but over 80% of moderate injury (MAIS =2) and approximately 50% of serious injury (MAIS 3+) is sustained with little or no intrusion to the compartment (<10cm). Approximately a third of driver fatalities also occur in the absence of major intrusion.

For drivers, the head, thorax, abdomen and lower extremities are the main body regions injured in fatal crashes. This reduces to the lower extremities and thorax for survivors of very serious (MAIS 3+) crashes with the upper extremity particularly noteworthy among moderately injured (MAIS =2) survivors of less serious crashes. A significant proportion of the upper extremity injury was fractures or dislocations of the right clavicle from seat belt loading

Larger vehicles form a greater proportion of the collision partners for the killed compared to the survivors and are likely to be directly associated with the higher injury rates for the head, thorax and abdomen body regions

ACKNOWLEDGEMENTS

This paper uses accident data from the United Kingdom's Co-operative Crash Injury Study (CCIS) collected during the period 1998 to 2006 (Phases 6 and 7).

Currently CCIS is managed by the Transport Research Laboratory (TRL Limited), on behalf of the United Kingdom's Department for Transport (DfT) (Transport Technology and Standards Division) who fund the project along with Autoliv, Ford Motor Company, Nissan Motor Company and Toyota Motor Europe. Previous sponsors include Daimler Chrysler, LAB, Rover Group Ltd, Visteon, Volvo Car Corporation, Daewoo Motor Company Ltd and Honda R&D Europe (UK) Ltd.

Data was collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre at Loughborough University; TRL Limited and the Vehicle & Operator Services Agency (VOSA) of the DfT

Further information on CCIS can be found at http://www.ukccis.org

REFERENCES

1. Road Casualties Great Britain: 2005, DfT National Statistics, see http://www.dft.gov.uk

2. Edwards M et al. (2003). 'Development of Test procedures and Performance Criteria to Improve Compatibility in Car Frontal Collisions', Paper No. 86, 18th ESV conference, Nagoya, 2003.

3. Edwards M et al. (2007). 'Current Status of the Full Width Deformable Barrier Test', Paper No. 88, 20th ESV conference, Lyon, 2007.

4. Cuerden R W, Hill J R, Kirk A, Mackay G M, 'The potential effectiveness of adaptive restraints'. Proceedings of the 2001 International IRCOBI Conference on the Biomechanics of Impact, Isle of Man, 10-12 October 2001

5. Hill J R, Mackay G M and Morris A P (1994), 'Chest and abdominal injuries caused by seat belt loading'. Accident Analysis and Prevention, 26 (1) 11-26.

6. www.euroncap.com

7. Mackay G M, Ashton S J, Galer M D and Thomas P D (1985). "The methodology of in-depth studies of car crashes in Britain." SAE technical paper number 850556: Society of Automotive Engineers Inc. (SAE), 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, U.S.A. pp. 365 390.

8. AAAM (1990). "The Abbreviated Injury Scale. 1990 Revision." Des Plaines, Illinois 60018, U.S.A: Association for the Advancement of Automotive Medicine (AAA).