Transport Research Laboratory

# Technical assistance and economic analysis in the field of legislation pertinent to the issue of automotive safety: provision of information and services on the subject of accident analysis for the development of legislation on frontal impact protection

Final Report

**by D Richards, M Edwards and R Cookson (TRL)**

**CPR815**

**ENTR/05/17.01**

**CLIENT PROJECT REPORT**

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# Technical assistance and economic analysis in the field of legislation pertinent to the issue of automotive safety: provision of information and services on the subject of accident analysis for the development of legislation on frontal impact protection

Final Report

**by D Richards, M Edwards and R Cookson (TRL)**

**Prepared for: Project Record:** **ENTR/05/17.01**

**Provision of Information and Services on the Subject of the Tests, Procedures and Benefits of the Requirements for the Development of Legislation on Frontal Impact Protection**

**Client:** **European Commission, DG Enterprise and Industry**

**(Peter Broertjes)**



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# Contents

# Executive summary

Frontal impact crash protection is currently legislated for in Europe by EC Directive 96/79/EEC or UNECE Regulation 94. Under the terms of the recently adopted General Safety Regulation, the existing Directive will be repealed and replaced by direct reference to the UNECE Regulation and its contents in 2014. Under a GRSP informal working group in Geneva a review of the requirements of Regulation 94 has been initiated which will potentially lead to proposals to amend this Regulation. One of the problems found during preliminary work performed was that the accident data available to review the current frontal impact situation in Europe was limited.

TRL was commissioned by the European Commission (EC) to perform a comprehensive European accident study for frontal impact to help prioritise frontal impact scenarios for casualty reduction, which will be used to help prioritise potential future changes to frontal impact legislation for both the short and longer term.

The specific objectives of the study were:

- To perform an analysis of European, national and detailed accident databases to determine the taxonomy of frontal impacts (i.e. classify the distribution of casualties in frontal impacts by impact configuration, injury type, casualty age and gender, etc.) and quantify casualty target populations for potential changes to frontal impact legislation.
- To perform detailed case analysis:
    - To review fatal injury cases in Regulation 94 compliant (or equivalent) cars in frontal impacts to help understand the reasons why they were killed, to help guide future improvements to Regulation 94.
    - To analyse the performance of vehicles involved in impacts similar to the Regulation 94 test to help understand how well this test represents real-world accidents to help guide future improvements to Regulation 94.
- To perform an analysis of car to other vehicle impacts to help understand the nature and magnitude of the compatibility problem.

To achieve these objectives, analysis of European, UK, German and French national and detailed level accident databases was performed. Because TRL did not have access to the German and French national and in-depth accident databases, access to and analysis of the German databases was provided by BASt and the French databases by LAB, under subcontract arrangements.

When appropriate as far as was possible only Regulation 94 compliant vehicles (or those with an equivalent safety level) were selected for the study to ensure that the results were representative of the performance of Regulation 94 compliant vehicles and hence appropriate for use to set priorities for an update of Regulation 94.

Throughout the analysis care was taken to ensure that the relationship between the accident data samples used to investigate specific factors, the whole database and the European picture was known, so that it was possible to scale back up to estimate what effect changing a particular factor may have on the European picture.

The work highlighted the following areas for further consideration for potential changes to frontal impact regulation:

- Measures to improve seat-belt usage (in particular for rear seat occupants and $N_1$ vehicle occupants)
- Introduction of a full width test
- Protection of older occupants
- Protection of rear seat occupants

- Protection against thorax injury (in particular for the elderly)
- Compatibility

# 1 Introduction

Frontal impact crash protection is currently legislated for in Europe by EC Directive 96/79/EEC or UNECE Regulation 94. Under the terms of the recently adopted General Safety Regulation, the existing Directive will be repealed and replaced by direct reference to the UNECE Regulation and its contents in 2014.

Under a GRSP informal working group in Geneva a review of the requirements of Regulation 94 has been initiated which will potentially lead to proposals to amend this Regulation. One of the problems found during preliminary work performed was that the accident data available to review the current frontal impact situation in Europe was limited. The last comprehensive and co-ordinated European accident analysis study was performed over 10 years ago to help review the frontal and side impact Directives (Wykes, 1998). As a result of limited accident data available it was not possible to prioritise definitely frontal impact scenarios for injury and fatality reduction and determine whether or not previously made recommendations to improve the legislation, for example, the introduction of a full width test, were still valid. This is necessary to help decide the best way forward for future regulatory improvements.

Previous work performed for the EC has identified two types of potential options to improve frontal impact regulation in the short term (Edwards *et al*. 2009). The first type consisted of changes to the test configuration and / or the addition of new tests, referred to as 'main' options. The second type consisted of options which could be incorporated into the 'main' options, such as changes to the dummy test tool and / or assessment criteria, referred to as 'supplementary' options. The options identified were:

'Main' options

1. No change.
2. Replace the current Regulation 94 ODB test with a Progressive Deformable Barrier (PDB) test as proposed by France at the December 2007 GRSP meeting.
3. Add a full width high deceleration test to the current UNECE Regulation 94 ODB test procedure.
4. Combination of options 2 and 3.

'Supplementary' options

Dummy related:

a. Incorporation of the THOR-Lx, and possibly the THOR upper leg, as a retro-fit to the Hybrid III dummy.

Other:

b. Extension of scope to include all vehicles of $M_1$ category and $N_1$ vehicles.
c. Steering wheel movement controlled through the addition of a 100 mm horizontal displacement limit.
d. Footwell intrusion controlled by assessment against a specifically developed criterion and associated pass or fail limit.
e. Assessment of protection afforded in rear seated positions.

In the longer term it is generally agreed that one of the next major steps to improve frontal impact regulation is to introduce an integrated set of test procedures to assess and control both a car's self protection and partner protection (compatibility) (EEVC 2007). It is recommended that this set of test procedures will contain both an offset test and a full width test. Other steps under consideration for the medium to longer term include improvement of protection for the full range of occupants, in particular for older occupants, female occupants and rear seated occupants. In addition measures to improve thorax protection are being considered for the longer term.

At present the GRSP informal working group on frontal impact aims to deliver a clear plan for potential future changes to Regulation 94 to GRSP in May 2011 and hence is considering potential options for changes and the evidence to support them.

TRL was commissioned by the European Commission (EC) to perform a comprehensive European accident study for frontal impact to help prioritise frontal impact scenarios for casualty reduction, which will be used to help prioritise potential future changes to frontal impact legislation for both the short and longer term.

The specific objectives of the study were:

- To perform an analysis of European, national and detailed accident databases to determine the taxonomy of frontal impacts (i.e. classify the distribution of casualties in frontal impacts by impact configuration, injury type, casualty age and gender, etc.) and quantify casualty target populations for potential changes to frontal impact legislation.
- To perform detailed case analysis:
    - To review fatal injury cases in Regulation 94 compliant (or equivalent) cars in frontal impacts to help understand the reasons why they were killed, to help guide future improvements to Regulation 94.
    - To analyse the performance of vehicles involved in impacts similar to the Regulation 94 test to help understand how well this test represents real-world accidents to help guide future improvements to Regulation 94.
- To perform an analysis of car to other vehicle impacts to help understand the nature and magnitude of the compatibility problem.

To achieve these objectives, analysis of European, UK, German and French national and in-depth accident databases was performed. Because TRL did not have access to the German and French national and in-depth accident databases, access to and analysis of the German databases was provided by BASt and the French databases by LAB, under subcontract arrangements.

This is the final report for the project. The layout of the report is as follows:

- Section 2 describes the approach taken for the work and highlights points such as how the accident data samples used were selected so that they contained only Regulation 94 compliant vehicles (or those with an equivalent safety) to ensure that the results of the work were appropriate to guide changes to the Regulation. Also highlighted is the point that the study identifies target population sizes (i.e. those casualties that could benefit from potential changes to the Regulation) so that in the future it can be used as the basis for a benefits analysis for specific changes to the Regulation.
- Section 3 describes the data sources used in this study and limitations they have which are relevant to this study.
- Section 4 describes the work to determine the taxonomy of frontal impacts using European and national databases. At a European and national level for the UK, Germany and France, the changes in the number of casualties over time were investigated. Next various factors were determined to help identify the size of the target population of casualties which could be affected by improvements to Regulation 94. At a European level this included the proportion of casualties who were occupants of $M_1$ and $N_1$ vehicles and which other vehicles were involved in the accidents. At a national level, for the UK, Germany and France, this included the number and severity of casualties and impact configurations. In addition a study was performed to compare the safety levels of 'old' cars with 'new' cars.
- Section 5 describes the continuation of the work of Section 4 using detailed accident databases. This includes the classification of frontal impacts by object hit, overlap, collision severity and other factors. It also includes the classification of injury types and mechanisms and the determination of the size of target

populations for potential specific changes to Regulation 94 such as the introduction of a full width test.

- Section 6 describes the detailed case analysis work to investigate how well the current Regulation 94 test represents real-world accidents. This work consisted of two parts. In the first part a review of fatal injury cases in Regulation 94 compliant (or equivalent) vehicles was performed to help understand the reasons why they were killed. The second part consists of a review of accidents of similar configuration to the Regulation 94 test to determine how well the test represents real-world accidents.
- Section 7 focuses on the compatibility problem and investigates factors such as the "severity proportion" (proportion of casualties who were killed or seriously injured) for vehicles by vehicle mass.
- Section 8 summarises the conclusions of the work.

It should be noted that the work performed has already been reported to the GRSP frontal impact informal working group to ensure that the group were aware of the findings of this study as early as possible.

# 2 Approach

The following accident databases were selected for use in this project to provide a European perspective and detailed accident data for the UK, Germany and France:

- European
    - CARE (Community database on Accidents on the Road in Europe).
    - Eurostat.
- UK
    - National police collected database (STATS19).
    - CCIS (Co-operative Crash Injury Study) detailed accident database.
    - HVCIS (Heavy Vehicle Crash Injury Study) detailed heavy vehicle fatals database.
- Germany
    - National police collected database.
    - GIDAS (German In Depth Accident Study) detailed accident database.
- France
    - National police collected database.
    - LAB detailed accident database.

Data for the European perspective was obtained from the CARE (Community database on Accidents on the Road in Europe) database. The CARE database contains information for most of the 27 European Union member countries, the notable exception being Germany. Data for Germany was obtained from the German national database. Also, further national data was obtained from the UK (STATS19) and French databases. Data for detailed accident studies was obtained for the UK, Germany and France from the CCIS (Co-operative Crash Injury Study), GIDAS (German In-Depth Accident Study) and LAB databases, respectively. These databases are the product of the three largest in-depth accident studies in Europe. For the UK, detailed data for $N_1$ type vehicles with a gross weight less than 3.5t was obtained from the HVCIS (Heavy Vehicle Crash Injury Study) fatals database, because comprehensive data for $N_1$ vehicles are not available in the CCIS database.

Because TRL did not have access to the German and French national and detailed accident databases, access to and analysis of the German databases was provided by BASt and the French databases by LAB, under subcontract arrangements. TRL worked in close harmony with BASt and LAB to ensure that the analysis of the national datasets of the different countries was compatible where possible, and where it was not possible, that the differences in the data were understood.

When appropriate as far as was possible only Regulation 94 compliant vehicles (or those with an equivalent safety level) were selected for the study to ensure that the results were representative of the performance of Regulation 94 compliant vehicles and hence appropriate for use to set priorities for an update of Regulation 94. The legal situation for frontal impact type approval within the European Union is:

- Since 1 October 1998 the Frontal Impact Directive 96/79/EC (equivalent to Regulation 94) was mandated for type approval of new vehicle types within the European Union.
- Since 1 October 2003 an approval was mandated for the first registration of a vehicle.

As a result of this all vehicles in the fleet registered since 1st October 2003 are Regulation 94 compliant and vehicles registered before this date may not be compliant. However, many vehicles registered between 1st Oct 1998 and 1st Oct 2003 will be compliant. In the accident data vehicle registration year information is available. Hence, this parameter was used to help select Regulation 94 compliant vehicles. The precise details of how this was achieved are given in Section 3 for each of the databases used.

One of the main objectives of the work was to quantify the target populations for potential changes to the legislation. The target population is defined as those casualties who are likely to experience some benefit from the countermeasure being considered, i.e. potential changes to Regulation 94. Identification of target populations is one of the first stages in a benefit analysis and is useful to give a first indication of the magnitude of the likely effect of potential changes being considered. The target population was estimated for various potential changes to Regulation 94. For example, as a first estimate the target population estimated was all car occupant casualties involved in frontal impacts as these casualties are likely to experience some benefit from changes to Regulation 94. However, unbelted casualties, those with an unbelted occupant seated behind them and those involved in roll-overs are unlikely to experience much benefit from the potential changes to Regulation 94 under consideration, so as a second estimate these casualties were removed from the target population. This target population was refined further to identify those casualties which are likely to benefit from specific changes to Regulation 94, such as the introduction of a full width test and countermeasures to improve protection for thorax injury.

Throughout the analyses care was taken to ensure that the relationship between the accident data samples used to investigate specific factors, the whole database and the European picture was known, so that it was possible to scale back up to estimate what effect changing that factor may have.

The work was divided into the following four tasks to address the specific objectives of the project:

1. Determination of frontal impact taxonomy using European and national databases
2. Determination of detailed frontal impact taxonomy using in-depth accident databases
3. Detailed case analysis to review fatalities and determine performance of current Regulation 94 test
4. Compatibility

Tasks 1 and 2 addressed the first objective of the project, namely to determine the taxonomy of frontal impact accidents in Europe and associated target populations.

Task 1 identified the breakdown of road accident casualties at a European level and determined target populations for potential changes to Regulation 94 at a national level for the UK, Germany and France. In addition, it investigated the effect of the introduction of the Regulation (and other measures to improve safety) by identifying the changes in the number of casualties since 1998 when the Regulation was introduced. Analysis was also performed to compare the crash safety levels of 'old cars' (i.e. those registered before the introduction of Regulation 94) and 'new cars' (i.e. those that were Regulation 94 compliant).

Task 2 extended the work of Task 1 and determined a more detailed breakdown of frontal impacts and associated target populations using detailed accident databases. For example, the distribution of casualties in frontal accidents by overlap was determined to help prioritise the relative importance of high, medium and low overlap type accidents, which provides useful information to help prioritise the importance of the potential changes to the legislation such as the introduction of a full-width test or a low overlap test. Differences between the UK and Germany were highlighted.

The relationships of the target populations identified in Tasks 1 and 2 to the national and European road accident casualty populations were clearly identified. This was important to ensure that the results of the work can be used as a basis for possible cost-benefit analysis type work in the future, which will be necessary to support proposals for changes to the Regulation.

Task 3 addressed the second objective of the project, namely to perform detailed case analysis to review fatal injury cases in Regulation 94 compliant (or equivalent) vehicles and to analyse the performance of vehicles involved in impacts similar to the UNECE Regulation 94 test to investigate how well the current Regulation 94 test represents real-world accidents and help identify any modifications which should be made to it. This task was performed using UK data only to minimise the total cost of the project. The purpose of the first part of the work was to help determine why people are still dying in frontal crashes despite seat belt use, airbags and the crashworthy structures of modern vehicles. NHTSA have recently performed a similar study (Bean et al., 2009). They concluded that the primary reasons why people were still killed were:

- The crash was exceedingly severe
- There was poor structural engagement between the vehicle and its collision partner
- The occupants were exceptionally vulnerable.

The purpose of the second part of the work was to determine how well the current Regulation 94 test represents what is important in real-world accidents to help identify any modifications which may be needed to the current test.

Task 4 addressed the third objective of the project, namely to perform an analysis of car to other vehicle impacts to help understand the nature and magnitude of the compatibility problem in frontal impacts. This work consisted of three parts. The first part investigated partner protection and determined an aggressivity ratio for different classes of impact partners (e.g. SUVs, small cars, large cars, etc) by comparing the severity of the casualties in the two vehicles. The second part investigated self-protection and determined the “severity proportion” (proportion of casualties who were killed or seriously injured) for vehicles by vehicle weight, adjusting for gender, age, etc. The third and final part investigated the relationship between mass ratio of the vehicles involved in the impact and injury severity of the drivers of these vehicles.

# 3 Data sources

In order to fulfil the requirements of this project, a number of different data sources were required, which are described in this section. This also includes a description of how the vehicles of interest (i.e. Regulation 94 compliant or equivalent) were selected in the databases.

## 3.1 European accident data

### *3.1.1 CARE*

The CARE (Community database on Accidents on the Road in Europe) project began in 1988, and collates the national accident data from different countries across the European Union into one combined database with common variables. This enables road safety problems to be investigated at the European level.

In the CARE database, it was assumed that $M_1$ vehicles can be selected by using the vehicle group "car + taxi", and $N_1$ vehicles can be selected by using the vehicle group "lorry, under 3.5 tonnes". It is not possible to distinguish between $M_1$ vehicles with a gross weight less than or greater than 2.5 tonnes, or to identify vehicles compliant with Regulation 94. It is also not possible to identify vehicles which had a frontal impact, or which objects they hit.

#### *3.1.1.1 Limitations of CARE*

The limitations of the CARE database are as follows:

- Does not include data from Germany.
- Only includes data for certain countries for certain years - there is no measure of the number of road casualties in Europe as a whole.
- Cannot identify object hit, or frontal impacts.
- Cannot identify $M_1$ vehicles with a maximum permitted mass over 2.5 tonnes.
- Cannot identify Regulation 94 compliant vehicles.

### *3.1.2 Eurostat*

Eurostat is the Statistical Office of the European Community, and collects statistics for the European Union, both at a European, national, and regional level. Eurostat was established in 1953, and includes statistics on many topics such as population, industry, the environment, and transport (Eurostat, 2009).

#### *3.1.2.1 Limitations of Eurostat*

The limitations of the Eurostat database are as follows:

- Only gives the total number of road traffic fatalities – cannot be broken down by road user type or impact type.

## 3.2 National accident data

### *3.2.1 National UK police data (STATS19)*

STATS19 is a database of traffic collisions in Great Britain that result in injury to at least one person and are reported to the police. When police attend a road traffic accident the officers on the scene fill out a series of standard forms. The database primarily records information on where the collision took place, when the collision occurred, the conditions at the time and location of the collision, details of the vehicles involved, and information about the casualties. This data is then collected, collated and analysed by the UK Department for Transport (DfT).

The severity of the casualties involved in the accident is assessed by the investigating police officer. Each casualty is recorded as being either slightly, seriously, or fatally injured. Fatal injury includes only casualties who died less than 30 days after the accident, not including suicides or death from natural causes. Serious injury includes casualties who were admitted to hospital as an in-patient. Slight injury includes minor cuts, bruises, and whiplash. The full definitions of these injury severities (and all other information recorded in STATS19) are given in the STATS20 document which accompanies the STATS19 form. These definitions are also available online at www.stats19.org.uk.

In the STATS19 database, $M_1$ vehicles can be identified as “cars” and “taxis / private hire cars”, and $N_1$ vehicles can be defined as “goods vehicles 3.5t gross weight and under”. It should be noted that this definition is slightly different to that present in the CARE database, as it includes vehicles with a mass of 3.5 tonnes. Vehicles where the first point of impact was to the front of the vehicle can be identified, and the partner vehicle or object can also be identified.

STATS19 has been linked to vehicle registration data from the Driver and Vehicle Licensing Agency (DVLA), which means that the date of registration is known for most of the vehicles in STATS19. Selecting vehicles registered in October 2003 or later was used as the best possible method of selecting vehicles which comply with Regulation 94.

#### *3.2.1.1 Limitations of STATS19*

The limitations of STATS19, the national accident database of Great Britain, are as follows:

- The “first point of impact” can be used to select frontal impacts, however this does not specify whether the vehicle went on to have a significant impact to another side.
- Only contains accidents reported to the police. While there are very few road fatalities which are not recorded in STATS19, comparison with other data sources suggests that a considerable proportion of non-fatal accidents are not reported to the police, and are therefore not recorded in STATS19 (Department for Transport, 2009).
- Impacts with objects and vehicles are recorded using two separate systems. When a vehicle has hit another vehicle and an object in the same accident, there is no way to identify which it has hit first. Therefore, when a vehicle hit an object and a vehicle, only the impact with the vehicle was counted in this study. Impacts with objects were counted when there was no impact with another vehicle. The object categories include the following codes from STATS19:
    - Car: includes “car” and “taxi / private hire car”
    - Bus: includes “minibus” and “bus or coach”
    - LGV: includes “goods vehicle 3.5 tonnes maximum gross weight (mgw) and under”
    - HGV: includes “goods vehicle over 3.5 tonnes mgw and under 7.5 tonnes mgw” and “goods vehicle 7.5 tonnes mgw and over”
    - Pole: includes “road sign / “traffic signal”, “lamp post”, and “telegraph pole / electricity pole”
    - Tree: includes “tree”

  - Wide object: includes "bridge – roof", "bridge – side", "bus stop / bus shelter", "central crash barrier", "nearside or offside crash barrier", and "entered ditch"
- Other / unknown: includes "pedal cycle", "motorcycle 50cc and under", "motorcycle over 50cc and up to 125cc", "motorcycle over 125cc and up to 500cc", "motorcycle over 500cc", "other motor vehicle", "other non-motor vehicle", "ridden horse", "agricultural vehicle", "tram / light rail", "previous accident", "roadworks", "parked vehicle", "bollard / refuge", "open door of vehicle", "central island of roundabout", "kerb", "other object", "any animal (except ridden horse)", and vehicles where no impact partner or object was recorded.

### *3.2.2 National German data*

In Germany, traffic accidents are documented by the police. Evidence is collected for forensic experts as well as for federal statistics held by Statistisches Bundesamt (STBA). Federal statistics are established for traffic accidents on public roads. Federal statistics are compiled on accidents due to vehicular traffic on public roads or places, with persons killed or injured or involving material damage. According to the law, the police authorities whose officers attended the accident are required to report. This implies that the statistics cover only those accidents which were reported to the police. These are primarily accidents with serious consequences. Traffic accidents involving only material damage or slight personal injuries are to a relatively large extent not reported to the police. Accidents are subdivided according to the "severity of the consequences", for example, road traffic accidents involving personal injury, severe accidents involving material damage, other accidents under the influence of alcohol and other accidents involving material damage only.

The criterion for the allocation is in each case the most serious consequence of the accident, i.e. in an accident with material damage only no casualties were involved. "Accidents with personal injury" are those in which persons were killed or injured irrespective of the amount of the material damage.

"Severe accidents involving material damage" are those whose cause is an irregularity or a road traffic offence. At the same time the motor vehicle has to be towed from the scene of the accident because of the damage (cannot be driven away). This includes accidents under the influence of alcohol. All other accidents with material damage where a road user involved was under the influence of alcohol have their full details recorded. All other accidents involving material damage are only numerically recorded by the locality of the accident (in town/village, out of town/village, on motorway). Here the locality of the accidents is determined by the yellow place name signs. All accidents occurring on motorways, including city expressways, are considered to be accidents outside built-up areas. In the case of accidents at road junctions, the higher-class road is coded.

Single-vehicle accidents involve only one vehicle, although several passengers may be injured or killed.

One reason for the differentiation according to the "severity of the consequences" is the intention not to excessively inflate the statistics of accidents and to record the large number of minor accidents only numerically in a breakdown by the locality of accidents. As a second reason, the definition of an accident involving personal injury is comparatively well suited for both international comparisons and the compilation of long-term time series. It is further presumed that the accuracy of the accident reports increases in proportion to the severity of the consequences of the accidents and that the data of accidents resulting in personal injury are more reliable than those of accidents causing only material damage. The structure of the characteristics of an accident however also changes in relation to its severity. For example, the share of vulnerable road users (pedestrians and two-wheel riders) involved in personal injury road accidents is greater than in accidents with material damage only.

Casualties are persons (incl. passengers) injured or killed in the accident. "Killed" includes all persons who died within 30 days as a result of the accident, "seriously injured" includes all persons who were immediately taken to hospital for inpatient treatment (of at least 24 hours), and "slightly injured" includes all other injured persons.

Regulation 94 compliant cars were selected using the year of registration of the vehicle. Any car registered in 2004 or later was included in the sample because these must have complied with the Regulation. Vehicles registered in 1998 to 2003 were included if they were models that were introduced or updated in 1998 or later, because these new vehicles would have also had to comply with the Regulation.

##### *3.2.2.1 Limitations of German national data*

The limitations of the German national data are as follows:

- In general, vehicles sustaining an impact to the front cannot be identified in the German national data. However, two-vehicle accidents involving a front-front or front-rear collision can be identified.
- The vehicle hit can be determined in a two vehicle accident by making the assumption that the two vehicles hit each other. However, the vehicle hit cannot be determined in an accident involving three or more vehicles.
- Maximum permitted mass is required to distinguish whether a goods vehicle is a light goods vehicle (LGV) or a heavy goods vehicle (HGV). For foreign vehicles involved in an accident on German roads the maximum permitted mass remains unknown. These goods vehicles cannot be placed into the LGV or HGV category.

### ***3.2.3 National French data***

The French national injury accidents database is a file that gathers all injury accidents investigated by police forces (police, Gendarmerie, CRS). This is a disaggregated database, which is a census of the injury road accidents in France. It describes the circumstances of each accident through a series of descriptive variables.

The data is collected at the local level and put together by the ONISR (Observatoire National Interministériel de Sécurité Routière), who are in charge of checking the consistency, correcting mistakes and establishing at least the official national file. This database is used each year by ONISR to make an assessment of the situation of road safety in France. An annual report describing the database is published each year (available in the middle of the following year).

Only descriptive information is available and there are some limitations. However, with experience in its use and some comparisons with other information (such as in-depth accident data collection for example) this database can be used for more than just simple analysis.

Regulation 94 compliant cars were selected in the French national data using the year of registration of the vehicle. Any car registered in 2004 or later was included in the sample.

##### *3.2.3.1 Limitations of French national data*

The limitations of the French national data are as follows

- Information is collected and coded by the police and not directly by experts on road accidents. No interpretation of the data is performed, only factual type things are recorded.

- An under-representation of accidents with very slight injuries.
- Up to the end of 2004, the French definition for the severity was different from that used in most European countries. Since 2005 this is no longer the case, but some errors could appear.
- The vehicle identification number is not correctly coded in most of the cases, but this situation is improving.
- Vehicles where the first point of impact is to the front of the vehicle are recorded. However, this also includes vehicles where the first point of impact on the vehicle has been on the side of the vehicle, towards the front.
- There is no consistent definition of LGVs in the French national data, therefore results of analyses using this data should be treated with great caution.
- In the same way as in the German national data, the vehicle hit cannot be determined in an accident involving three or more vehicles.
- The definition of "serious" injury was altered in 2005, therefore the number of serious casualties in 2005 or later cannot be compared to the number of serious casualties occurring in 2004 or earlier.
- For object hit, the breakdown is similar to that for Great Britain, although the object hit categories differ slightly because of the information available in the French national accident data. Impacts with poles, trees, and wide objects have been combined into one category which includes impacts with any type of object, there is an "other vehicle" category, and a "3 or more vehicle" category. This final category exists because it is not possible to determine which vehicle has hit which in an accident involving three or more vehicles.

## 3.3 In-depth datasets

### *3.3.1 Great Britain – CCIS*

The Co-operative Crash Injury Study (CCIS) collected in-depth real world crash data from 1983 to 2010. Vehicle examinations were undertaken at recovery garages several days after the collision. Car occupant injury information was collected from hospitals and questionnaires sent to survivors. Multi-disciplinary teams examined crashed vehicles and correlated their findings with the injuries the victims suffered to determine how the car occupants were injured. The objective of the study was to improve car crash performance by developing a scientific knowledge base, which has been used to identify the future priorities for vehicle safety design as changes take place.

Accidents were investigated according to a stratified sampling procedure, which favoured cars containing fatal or seriously injured occupants as defined by the British Government definitions of fatal, serious and slight. In order for an accident to be included in the study, a "newer" car must have been involved – one that was 7 years old or younger at the time of the accident. More information on the data collection methods employed can be found at www.ukccis.org. CCIS data collected from June 1998 to August 2009 have been used for this study.

The stratified sampling procedure means that CCIS records a relatively large number of fatal and serious accidents, which are often the most interesting from an injury prevention point of view. The representativeness of CCIS is discussed further in Appendix A.

Regulation 94 compliant (or equivalent) cars were selected using the year of registration, and a list of makes and models which were known to be compliant with the Regulation. Any vehicles registered in 2004 or later were selected, and also vehicles registered in

2000-2003 which were known to be compliant with (or have frontal impact protection equivalent to) Regulation 94.

Narrow objects are defined as an object (not including other vehicles, animals, or pedestrians) which is less than 41cm wide. Any object wider than this is classed as a wide object.

#### *3.3.1.1 Limitations of CCIS*

Limitations of the Co-operative Crash Injury Study are as follows:

- The stratified sampling procedure means that fatal and serious accidents are over-represented in the database compared to the national proportion. This needs to be taken into account when performing analysis, or the results need to be weighted by injury severity.
- Because the study concentrates on relatively new vehicles, if an old vehicle is included it is because it was in an impact with a new vehicle. This can affect the representativeness of analysis, but should not have a large effect for this analysis as only Regulation 94 compliant vehicles are being included.
- CCIS only examines cars in detail. Although impacts between cars and other vehicles are included, only basic details of the other vehicles are included in the database.
- CCIS does not collect evidence from the scene of the accident. This means that there is not much information about the accident configuration and road user behaviour except what can be determined from the vehicle examinations.

### ***3.3.2 Great Britain – HVCIS fatals database***

The Heavy Vehicle Crash Injury Study fatals database contains information extracted from police accident files on fatal collisions involving at least one of the following types of vehicle:

- Heavy goods vehicles (HGVs)
- Light goods vehicles (LGVs, excluding car-derived vans)
- Other motor vehicles (OMVs)
- Agricultural vehicles
- Large passenger vehicles (LPVs)
- Minibuses

The HVCIS project was created to determine the likely causes and personal injury consequences of accidents involving the vehicles described above. This ongoing project studies the detailed police files relating to fatal accidents, thus providing detailed information on specific accident types.

The database only contains information on fatal accidents and cannot be used to investigate the characteristics of non-fatal accidents. This study looked at fatalities in LGVs which occurred between 1995 and 2008. Because $N_1$ vehicles are not included in current frontal impact legislation, all ages of LGVs were included.

#### *3.3.2.1 Limitations of HVCIS fatals database*

The limitations of the HVCIS fatals database are as follows:

- The database only contains fatal accidents, so cannot be used to investigate the characteristics of non-fatal accidents.

- Because the information is recorded from police accident investigation reports, the amount of information included can vary substantially from case to case.

### *3.3.3 Germany – GIDAS*

The German In-Depth Accident Study (GIDAS) is Germany's largest accident collection study. It began in 1999 and collects about 2,000 accidents per year in the areas of Hanover and Dresden. The project is supported by the Federal Highway Research Institute (BASt) and the German Association for Research in Automobile Technology (FAT).

GIDAS includes all accident types, and the accidents included in the study are selected so that the study is representative of the national population of accidents. More information can be found at www.gidas.org.

Regulation 94 compliant (or equivalent) cars were selected using two processes. The first was based only on the year of registration – any vehicle registered in 2004 or later was included in the sample, because these must have complied with the Regulation. Vehicles registered in 1998 to 2003 were included if they were models that were introduced or updated in 1998 or later, because these new vehicles would have also had to comply with the Regulation.

#### *3.3.3.1 Limitations of GIDAS*

The limitations of GIDAS are as follows:

- Because the database is representative of the national accident statistics, this can mean that there are few accidents involving more severe or fatal injury.

### *3.3.4 France – LAB database*

The LAB database was set up in 1969 when the two French car manufacturers, Renault and PSA, joined forces to create a common laboratory. This database has been the main research tool for the LAB's passive safety and biomechanical work over the past 37 years. Five accident investigators from LAB and CEESAR input some 600 vehicles into the database each year. Two geographical zones are currently investigated, with different case selection criteria. In the North-West of the Yvelines department (near Paris), between 200 and 300 cars are studied each year, regardless of make and model.

In addition, national police accident reports are examined on a monthly basis in order to find accidents involving specific newer models. Analysis of these accidents provides feedback on the real world crashworthiness of another 300 or so late generation vehicles, their active and passive safety equipment and the specific injuries sustained by their passengers.

The database currently contains information on approximately 13,000 vehicles and 24,000 occupants. Regulation 94 compliant (or equivalent) cars were selected based on year of registration (any vehicles registered in 2004 or later were included in the sample), and based on make and model (any models of vehicle which were known to be Regulation 94 compliant or equivalent were included in the sample) for cars registered before 2004.

#### *3.3.4.1 Limitations of LAB database*

The limitations of the LAB database are as follows:

- The LAB in-depth database includes a relatively small number of accidents involving new vehicles compared to CCIS and GIDAS, which makes it difficult to study Regulation 94 compliant cars in as much detail.

# 4 Task 1: Determination of frontal impact taxonomy using European and National databases

## 4.1 Introduction

The objective of this task was to perform an analysis of European and national accident databases to determine the taxonomy of frontal impacts (i.e. classify the distribution of casualties in frontal impacts by impact configuration, injury type, casualty age and gender, etc.) and quantify casualty target populations for potential changes to frontal impact legislation. In addition, work was performed to investigate the differences in the safety levels of 'old' cars (i.e. those registered before the introduction of Regulation 94) and 'new cars' (i.e. those that were Regulation 94 compliant).

## 4.2 Description of work

The analysis was split into three sections, which investigated the changes in road accident and in particular car occupant casualties over time, the identification of target populations, and the differences in safety levels of old and new cars.

### *4.2.1 Changes over time*

To investigate the effect of the introduction of the frontal and side impact Regulations and other measures to improve safety, such as Euro NCAP, the European and national accident data was used to determine the changes in the number of frontal impact casualties since 1998 when the Regulation was introduced.

- Data from Eurostat were used to show how the total number of road fatalities in Europe has changed since the frontal impact legislation was introduced in 1998. This change was compared the change seen in the United Kingdom, Germany, and France.
- Data from CARE and the national datasets of Great Britain, France, and Germany were used to determine how car and LGV fatalities have altered since 1998.

### *4.2.2 Identification of target populations*

In order to review the current frontal impact situation in Europe, the size and taxonomy of the frontal impact population was determined. Data for the number of road fatalities in Europe as a whole was obtained from Eurostat. More detailed data for European countries was obtained from CARE (Community database on Accidents on the Road in Europe), which gives an overview of the number and severity of car ($M_1$) and light goods vehicle ($N_1$) occupant casualties. CARE could not be used to investigate frontal impacts; it only provides an overview of the number and severity of casualties in impacts of all configurations. However, it does provide data on what other vehicles were involved in the accidents with the $M_1$ or $N_1$ vehicles.

The taxonomy of frontal impacts in a subset of European countries (Great Britain, Germany, and France) was then determined using national accident data from those countries.

The taxonomy of frontal impacts for cars registered in all years was determined, and used to define target populations. The casualties in these populations who were in cars registered in 2004 or later were then investigated, to see if there were any changes for these cars which meet the requirements of Regulation 94, and how this affected the target populations. The size of the target populations was then adjusted, to estimate the size of the target population once the entire fleet is compliant with Regulation 94.

The following analysis was performed:

- National data from Great Britain and France were used to estimate the size of the target populations for potential changes to Regulation 94.
- The characteristics of the frontal impact datasets in the two countries were determined with respect to location of accident, gender, age, seating position, and vehicle mass.
- The target populations for $M_1$ vehicles were then adjusted to estimate the number of casualties assuming that the entire fleet was compliant with Regulation 94.

### *4.2.3 Safety levels of new cars compared to old cars*

The safety of old and new vehicles was compared by calculating the "severity proportion" for different ages of vehicle. The severity proportion for a given injury severity was defined as the number of casualties of that severity, divided by the total number of casualties. This is one method of comparing different populations to compare the safety levels of old and new cars. However, it should be noted that there are a number of limitations to this approach when comparing the severity proportions of vehicles of different ages:

- Results cannot be compared directly between different countries because of various reasons, e.g. recording of slight and serious casualties by police forces differs.
- Does not take account of confounding factors, such as type of driver, mass of vehicle, type of vehicle, driver age and gender, impact severity.
- Does not take account of any change in the number of drivers who are not injured in an impact.

Another approach which can give more control over confounding factors is to use a 'paired' type of analysis which is based on individual vehicle-to-vehicle impact pairs. However, this type of analysis is more complex and there was insufficient budget in the current project to perform this work.

The "fatal proportion" was used to give the severity proportion of fatalities, and the "KSI" proportion was used to give the severity proportion for fatal and serious casualties. The "Fatal proportion" was defined as the proportion of fatally injured car drivers to the total number of car driver casualties as shown in Equation 4-1.

$$Fatal\ proportion = \frac{fatal}{fatal + serious + slight} \quad \textbf{Equation 4-1}$$

"KSI proportion" was defined as the proportion of killed and seriously injured drivers to the total number of car driver casualties as shown in Equation 4-2.

$$KSI\ proportion = \frac{fatal + serious}{fatal + serious + slight} \quad \textbf{Equation 4-2}$$

The severity proportions were calculated using accident data from 2005-2008 inclusive. Four years of data were used so that the sample size was large enough to be able to see statistically significant differences between proportions. These differences were tested using a Z-test to determine whether they were significant.

The cars were divided into the following categories by year of registration to identify 'old cars' (i.e. those registered before the introduction of Regulation 94) and 'new cars' (i.e. those that were Regulation 94 compliant):

- Pre Oct 1994 — Very old cars
- Oct 1994 – Sep 1998 — 'Old' cars registered before introduction of Regulation 94
- Oct 1998 – Sep 2003 — Mixture of 'old' and 'new' cars
- Oct 2003 or later — 'New' cars compliant with Regulation 94

The safety levels of 'old' and 'new' cars were investigated as follows:

- The severity proportion for car drivers was determined with respect to the age of their vehicle, to investigate if newer cars are safer than older cars in all frontal impacts.
- For car-to-car frontal impacts the age of the impact partner was then taken into account to investigate whether impacts between two new cars are safer than impacts between two old cars.

## 4.3 Findings

### *4.3.1 Changes over time*

This section identifies the changes in road user casualties since the frontal impact Directive / Regulation came into force in 1998. Figure 4-1 shows the trend of road user fatalities from 1998 to 2008, demonstrating that the number of road accident fatalities has fallen substantially. The data for the EU in 2008 was not available at the time of writing, however in 2007 the number of road user fatalities in the 27 EU countries had decreased by 27%. How much the legislation and other secondary safety measures have contributed to this is uncertain. Figure 4-1 also shows the subset of fatalities from the UK, France and Germany; in 2007 the road user fatalities in these countries accounted for 7%, 11% and 12% of the fatalities of the 27 EU countries respectively, a total of 29%.

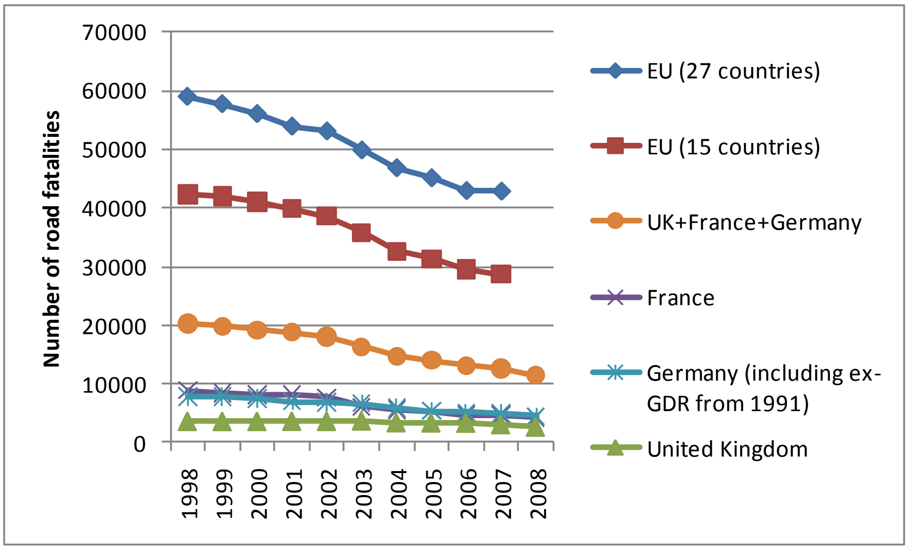


**Figure 4-1. Road user fatalities in EU 1998-2008 (Eurostat and national data)**

Some estimates of how much secondary safety measures have contributed to the fall in road accident fatalities have been made by other studies.

Broughton (2003) used car accident data from GB between 1980 and 1998 to estimate the effect on the number of driver casualties of the gradual improvement in the secondary safety features of the national car fleet. Statistical models were used to confirm that the proportion of car drivers who were killed or seriously injured (KSI) was lower among more modern cars. Broughton also argued that this reduction could be used to assess the casualty reductions brought about by improved secondary safety. He estimated that, of the casualties that would have occurred in 1998, if all cars had the level of secondary safety found in cars first registered in 1980, improved secondary safety reduced the number of drivers who were KSI by at least 19.7 %. This figure relates to all cars on the road in 1998, but when confined to the most modern vehicles (those first registered in 1998) rises to 33 %.

Figure 4-2 shows the number of road user fatalities for France, Germany and the UK. The largest percentage drop in fatalities is seen in France with a 48% decrease, followed by Germany with a 36% decrease. The UK's decrease in fatalities was lower at 15%. However, it should be noted that for the UK in 2008, the number of road fatalities was the lowest per head of population with only 43.4 road user deaths per million people, compared to 66.8 in France and 54.6 in Germany. (NB: These numbers were calculated by assuming populations in 2008 of 64 million in France, 82 million in Germany and 61 million in the UK).

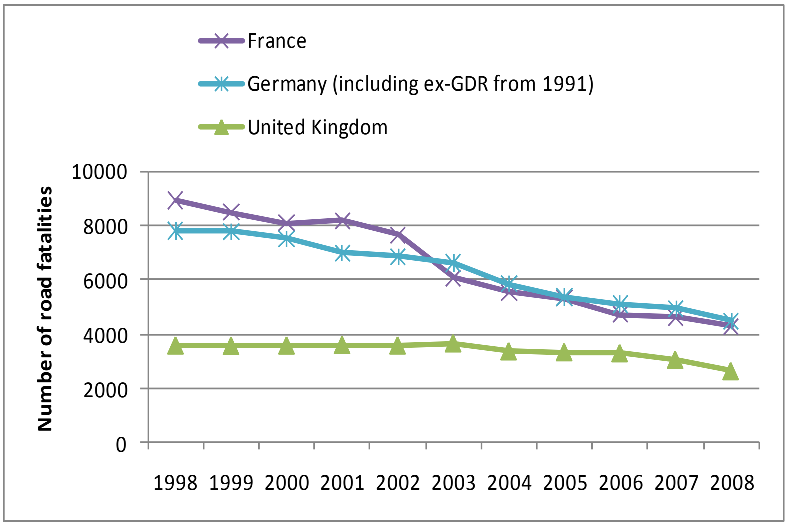


**Figure 4-2. Road casualties in Germany, France, UK, 1998-2008 (Eurostat and national data)**

#### *4.3.1.1 Car ($M_1$) and light goods vehicle ($N_1$) occupant fatalities 1998-2008*

Figure 4-3 splits the number of road fatalities by those who were in cars ($M_1$) and light goods vehicles (LGVs, $N_1$). This illustrates the low number of LGV ($N_1$) fatalities compared to car ($M_1$) fatalities, and shows the small increase in target population that would be achieved by including LGV ($N_1$) vehicles within the scope of Regulation 94. However, this alone does not indicate that such a scope change should not be considered further. This is because the number of LGVs compared to cars is also low which means that the total costs to modify them could also be low, which in turn means that the cost benefit ratio of this possible change to the Regulation could be better than the ratio for other possible changes for cars.

The number of LGV ($N_1$) fatalities is low for all three countries. There was a 26% decrease in the number of car ($M_1$) fatalities from 1998 to 2008 in GB and a 36% decrease in LGV ($N_1$) fatalities. In Great Britain, the car ($M_1$) and LGV ($N_1$) fatalities account for 51% of all road user fatalities, which is the same percentage as in 1998.

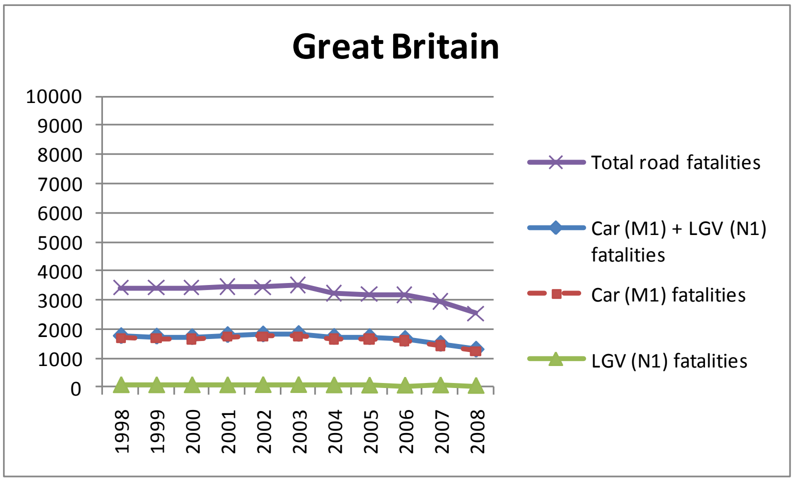


**Figure 4-3. Car ($M_1$) and LGV ($N_1$) occupant fatalities 1998-2008 in GB (CARE and national data)**

Figure 4-4 shows this trend for the French data, which had a 62% drop in car ($M_1$) fatalities and an 11% decrease in LGV ($N_1$) fatalities. In France, the car ($M_1$) and LGV ($N_1$) fatalities account for 55% of all road user fatalities in 2008 compared to 67% in 1998. However, the French national data has not recorded LGV casualties in a consistent way over this time period, so any analysis of the number of LGV fatalities in France should be treated with caution.

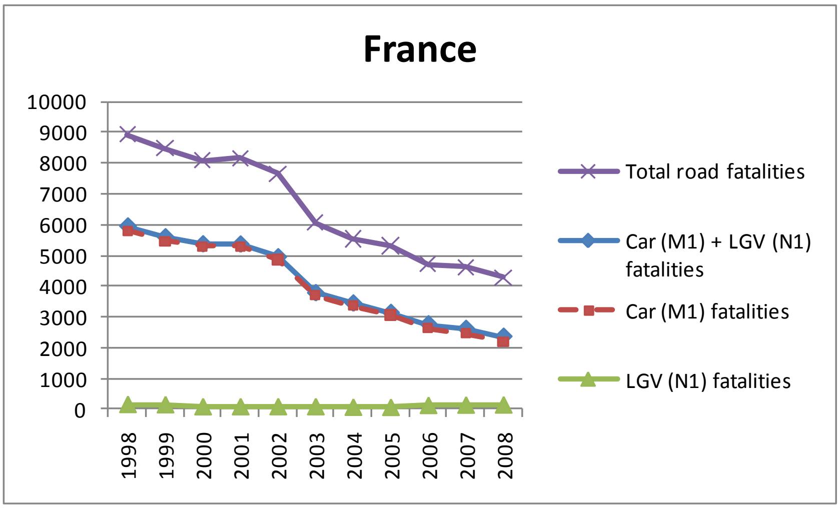


**Figure 4-4. Car ($M_1$) and LGV ($N_1$) occupant fatalities 1998-2008 in France (CARE and national data)**

Figure 4-5 shows this trend for the German data, which had a 50% drop in car ($M_1$) fatalities and a 5% increase in LGV ($N_1$) fatalities. In Germany, the car ($M_1$) and LGV ($N_1$) fatalities account for 55% of all road user fatalities in 2008 compared to 62% in 1998.

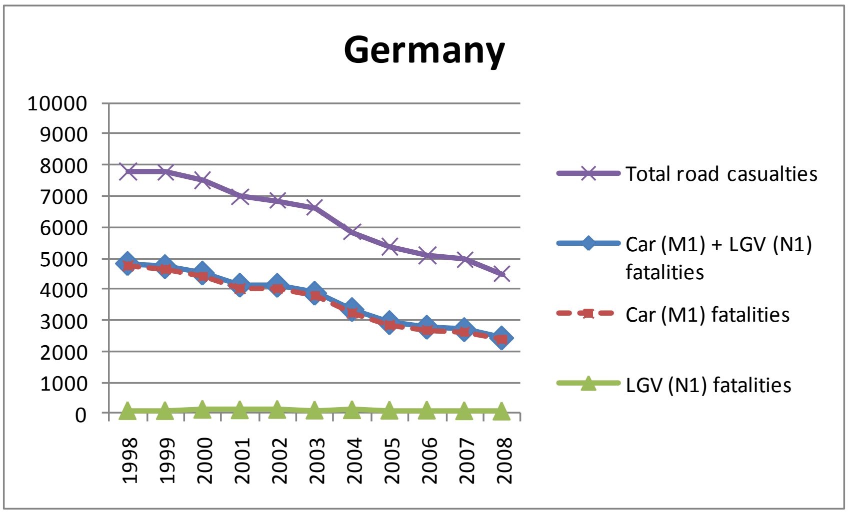


**Figure 4-5. Car ($M_1$) and LGV ($N_1$) occupant fatalities 1998-2008 in Germany (CARE and national data)**

### *4.3.1.2 Road class*

The following graphs show the road fatalities split by road class. These road classes are rural, urban and motorway. In Great Britain, the majority of car ($M_1$) occupant fatalities occur in rural areas (60% in 1998 and 2008) and a minority are on motorways, the percentage of which is gradually increasing over time (6% in 1998 to 8% in 2008). For all road fatalities in Great Britain, the percentage of accidents on rural roads has remained constant at 60%, and the percentage on motorways has increased from 4% to 6%.

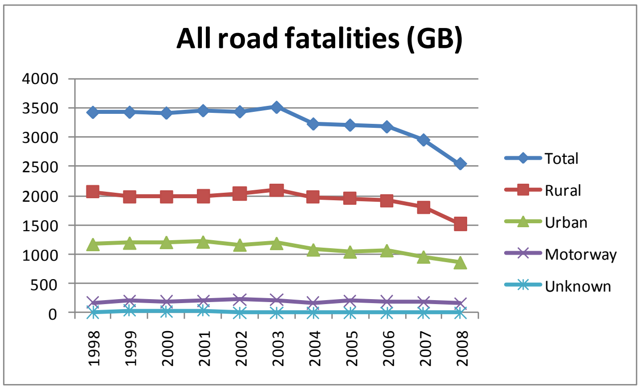


**Figure 4-6. Road type for all road fatalities in GB**

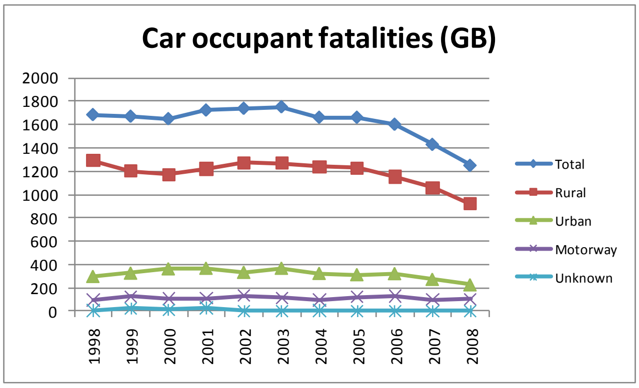


**Figure 4-7. Road type for car occupant fatalities in GB**

In France, a similar pattern is seen compared to GB with the majority of car ($M_1$) occupant fatalities occurring in rural areas (71% in 1998 and 79% in 2008) and a minority on motorways, the percentage of which (7%) has remained constant over time. For all road fatalities in France, the percentage of accidents on rural roads has increased from 63% in 1998 to 65% in 2008, and the percentage on motorways has remained at 6%.

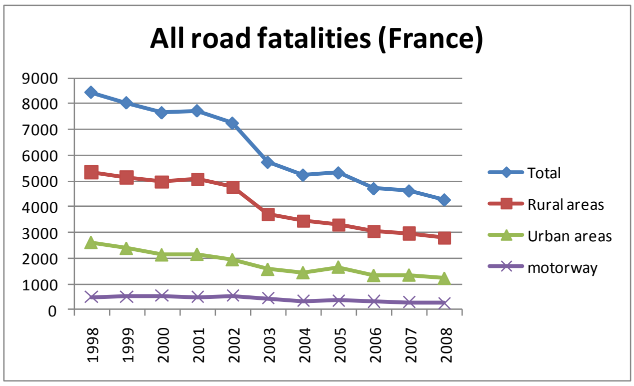


**Figure 4-8. Road type for all road fatalities in France**

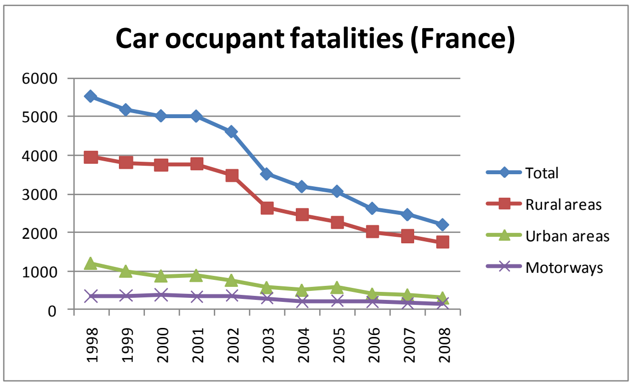


**Figure 4-9. Road type for car occupant fatalities in France**

In Germany, a similar pattern is also seen compared to GB and France with the majority of car ($M_1$) occupant fatalities occurring in rural areas (76% in 1998 and 75% in 2008) and a minority on motorways, the percentage of which has increased slightly over time from 13% in 1998 to 14% in 2008. For all road fatalities in Germany, the percentage of accidents on rural roads has decreased from 65% in 1998 to 61% in 2008, and the percentage on motorways has also increased slightly from 10% to 11%.

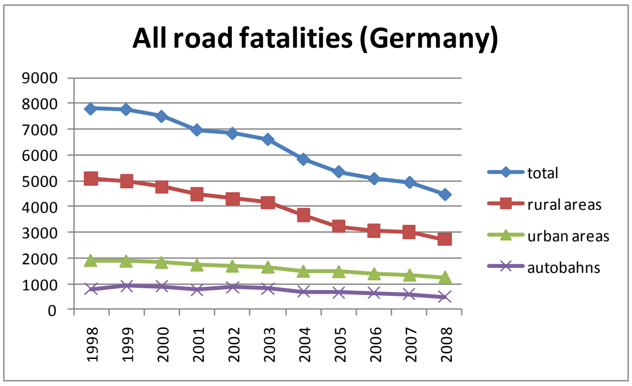


**Figure 4-10. Road type for all road fatalities in Germany**

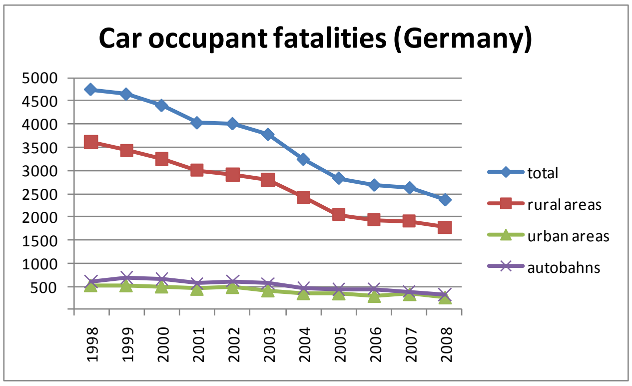


**Figure 4-11. Road type for car occupant fatalities in Germany**

### *4.3.1.3 Object Hit*

It is important to identify the types of objects that vehicles are striking. The classifications of objects hit are recorded slightly differently in the three countries. In Great Britain, the percentage of car occupant fatalities where the object hit was another car has decreased slightly between 1998 and 2008 from 39% to 35% as shown in Figure 4-12 and Figure 4-13. In Germany the reduction has been smaller for those who struck cars, from 25% to 24%, with a reduction from 30% to 24% in France. The percentage of car occupant fatalities in cars that struck other cars is much higher in Great Britain than in France and Germany. However, this is thought to be due to the different police collection methods. For example, in Great Britain if a car hits an object followed by an impact with a car, it is not possible to determine which object was hit first, so in this study it has been assumed that the car was hit first.

In Great Britain, the accident involved a single vehicle for 46% of car occupant fatalities (includes pole, tree, wide object, and other/unknown) compared to 42% in Germany and 43% in France (includes wide object, tree and pole).

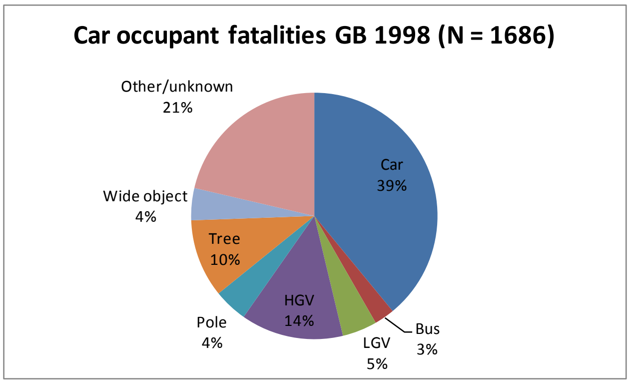


**Figure 4-12. Object Hit in 1998 in GB (national data)**

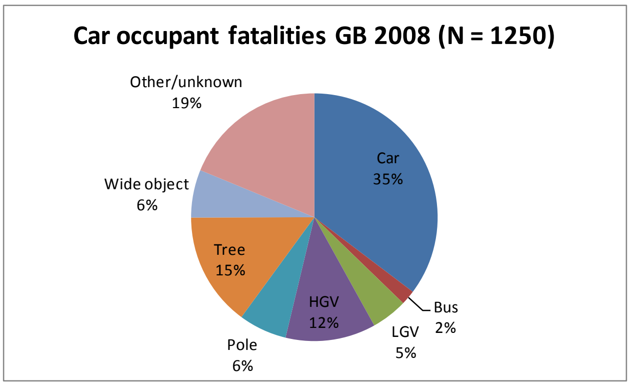


**Figure 4-13. Object Hit in 2008 in GB (national data)**

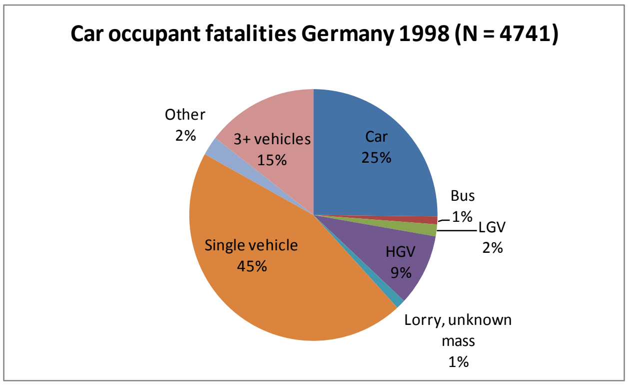


**Figure 4-14. Object Hit in 1998 in Germany (national data)**

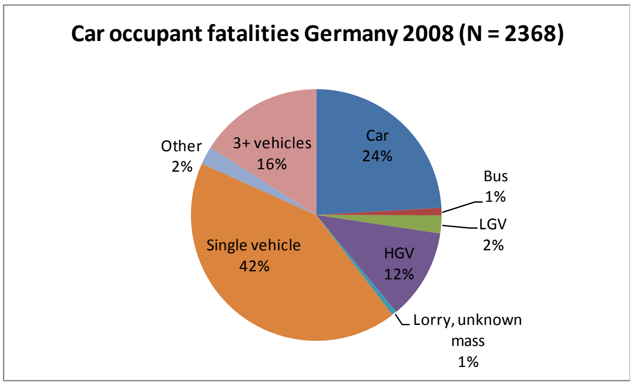


**Figure 4-15. Object Hit in 2008 in Germany (national data)**

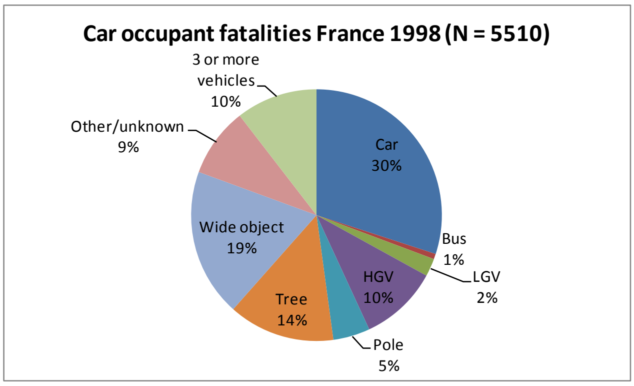


**Figure 4-16. Object Hit in 1998 in France (national data)**

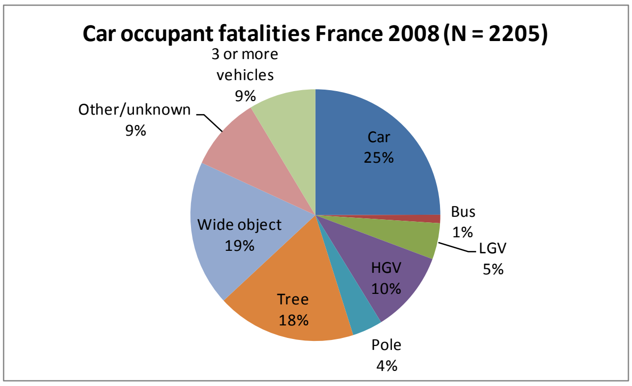


**Figure 4-17. Object Hit in 2008 in France (national data)**

### *4.3.2 Identification of target populations*

Using the national data from GB and France for 2008 the target populations for possible changes to the frontal impact legislation were identified using a number of different stages. This could not be performed for Germany, because the German national data does not record the impact side for all types of accident.

The first stage involved identification of the number of casualties in cars ($M_1$) and LGVs ($N_1$) by impact configuration (i.e. front, side, rear etc.) and by object hit for frontal impacts.

The second stage involved analysis of the characteristics of casualties in frontal impacts, such as the age, gender, seating position, and vehicle mass.

The final stage estimated the effect on the target population size of the assumption that the car fleet that was fully compliant with Regulation 94.

#### *4.3.2.1 Distribution of casualties*

Figure 4-18 shows the breakdown of casualties for car ($M_1$) occupant casualties in Great Britain for accidents occurring in 2008. The percentages at each level give the percentage of car ($M_1$) fatalities or seriously injured occupants which are included in that group.

The first split in this figure is by impact type. Front, side, and rear impacts are defined by the first point of impact for that vehicle. In STATS19, rollovers are identified using a separate system, therefore some of the vehicles which rolled over may also have had the first point of impact to the front, side, or rear, so casualties in these impacts will be counted twice in the figure.

The next split of casualty numbers takes only those casualties where the first point of impact was to the front of their vehicle, and breaks these down by the object that the vehicle hit in that frontal impact. A definition of the STATS19 object hit categories can be found in section 3.2.1.

The proportion of fatal and serious casualties in Figure 4-18 were compared to the proportions for accidents occurring in 2005-2008 using a chi-squared test, however no significant differences were found.

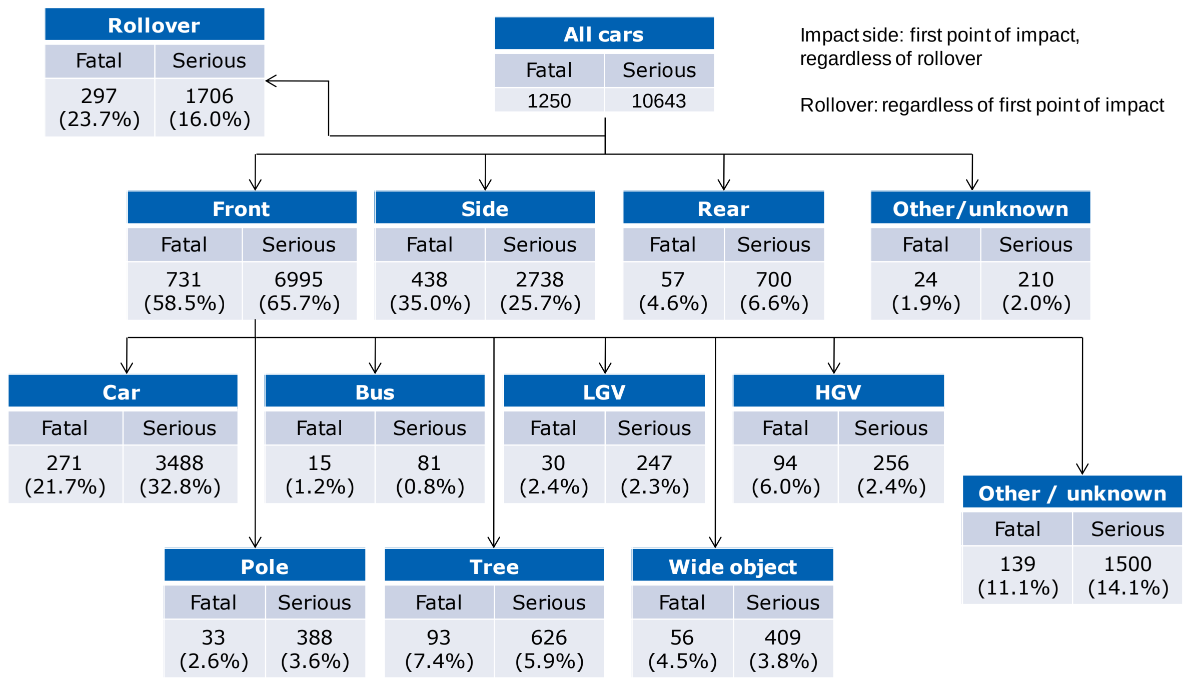


**Figure 4-18. Breakdown of casualty numbers for Great Britain in 2008 – cars**

Figure 4-19 shows the breakdown of casualty numbers for car ($M_1$) occupant casualties in France for accidents occurring in 2008. The proportion of casualties in Figure 4-19 was compared to the proportion of casualties in accidents occurring in 2005-2008. Some small significant differences were seen for the object hit for vehicles containing serious casualties. These were an increase in the proportion of serious casualties in impacts with LGVs (2.0% in 2005-2008, 2.5% in 2008), an increase in the proportion of serious casualties in impacts with other vehicles (1.5% in 2005-2008, 2.1% in 2008), and a decrease in the number of serious casualties in accidents involving 3 or more vehicles (7.5% in 2005-2008, 7.0% in 2008).

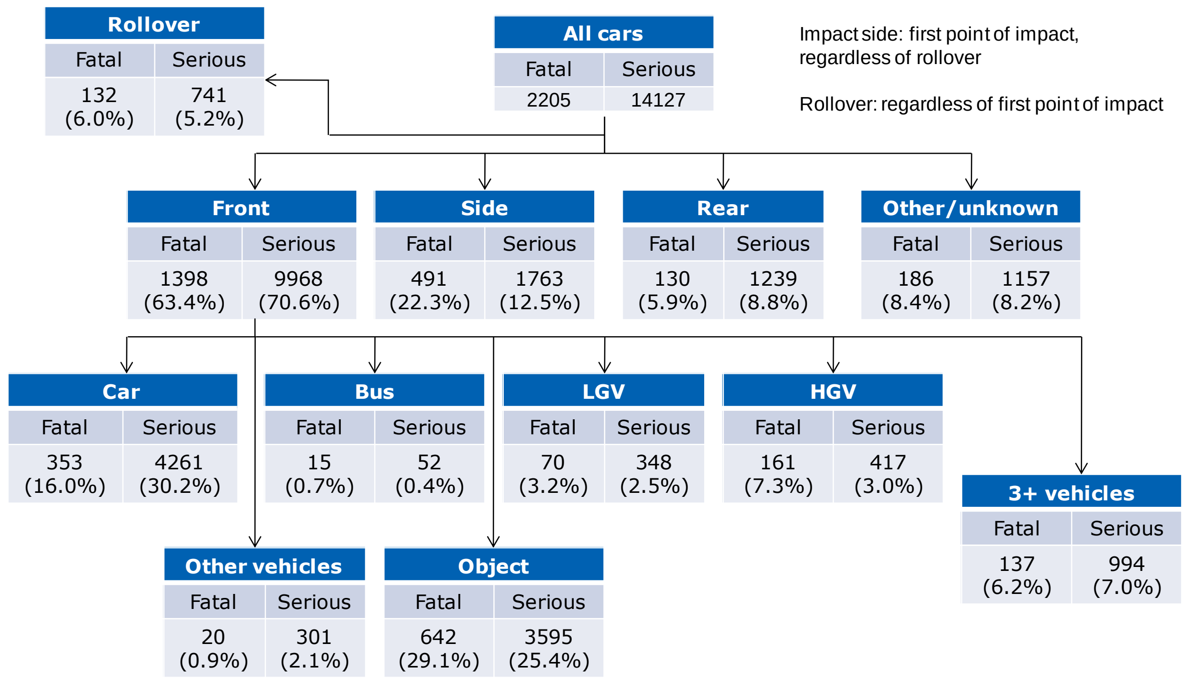


**Figure 4-19. Breakdown of casualty numbers for France in 2008 - cars**

Figure 4-20 shows the breakdown of casualty numbers for LGV ($N_1$) occupant casualties in Great Britain for accidents occurring in 2008. There were no significant differences when comparing the proportions of casualties in 2008 to the proportions in 2005-2008. The same information is not shown for LGVs ($N_1$) in France, because there is no consistent definition of LGVs in the French national data.

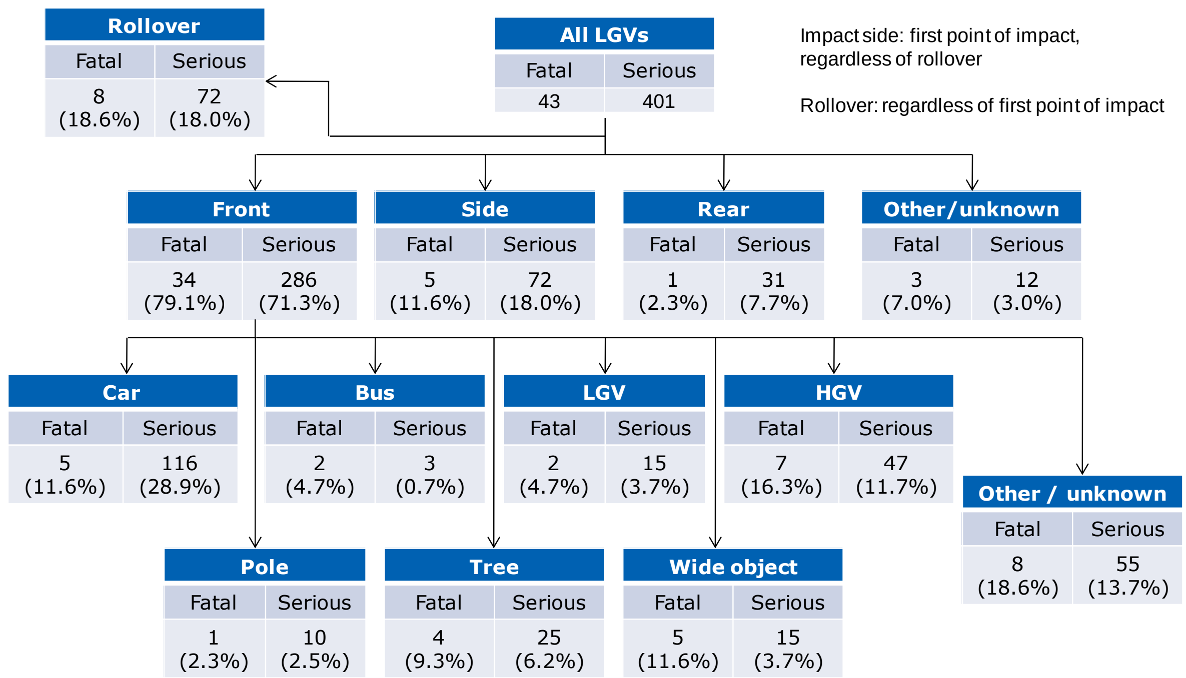


**Figure 4-20. Breakdown of casualty numbers for Great Britain in 2008 - LGVs**

### *4.3.2.2 Characteristics of frontal impact population*

The characteristics of the frontal impact population were compared for car ($M_1$) occupant casualties in the national data from Great Britain and France.

Figure 4-21 and Figure 4-22 show the location of the accident for car occupant casualties in frontal impacts in Great Britain and France respectively, for accidents which occurred in 2008. The proportions are similar in both countries, and show that more severe accidents occur most often in rural areas.

These distributions were compared for all cars, and cars registered on 1st October 2003 or later (new cars), and statistically significant differences were found for both countries. In Great Britain, the percentage of fatal casualties occurring in urban areas was higher for new cars (16.3% for all cars, 19.4% for new cars). In France, the percentage of fatal casualties in urban areas was lower for new cars (13% for all cars, 11% for new cars).

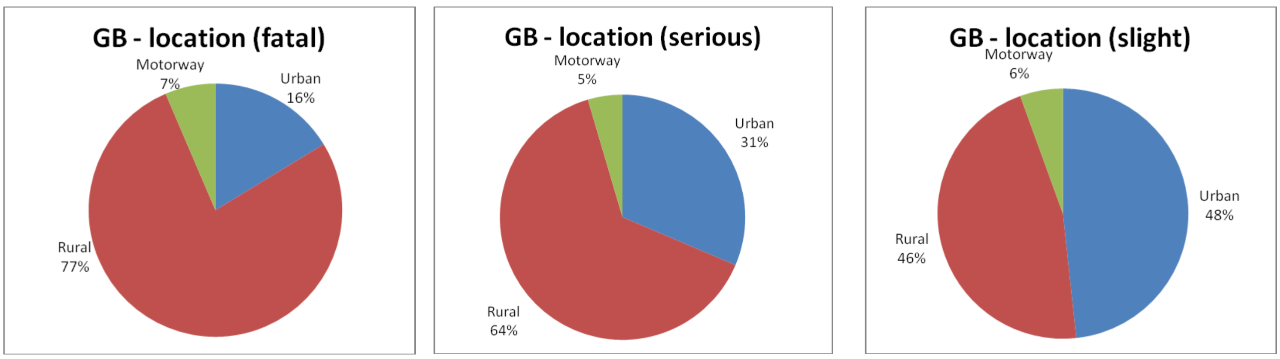


**Figure 4-21. Location of accident for car occupant casualties in frontal impacts in Great Britain, 2008**

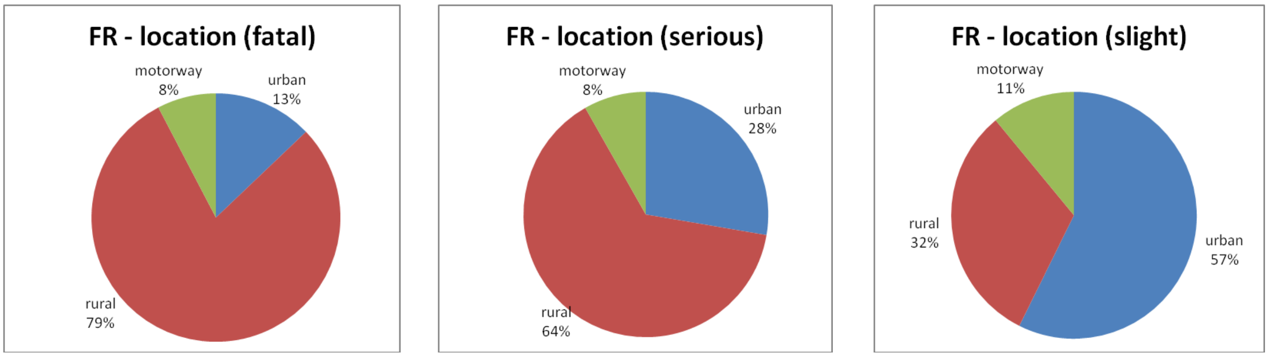


**Figure 4-22. Location of accident for car occupant casualties in frontal impacts in France, 2008**

Figure 4-23 and Figure 4-24 show the gender of the car occupant casualties in frontal impacts for Great Britain and France respectively. The proportions in both countries are similar, and both show the same trend that male casualties are more likely to be involved in fatal accidents.

The proportions for all cars and new cars were compared. Significant differences were found in Great Britain, but not in France. In Great Britain, the proportion of seriously injured male casualties was smaller for new cars (60.4% for all cars, 57.3% for new cars).

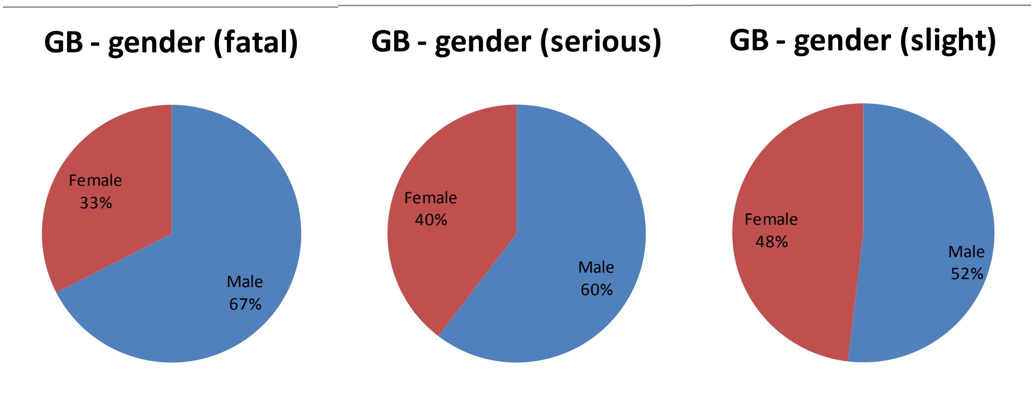


**Figure 4-23. Gender of car occupant casualties in frontal impacts in Great Britain, 2008**

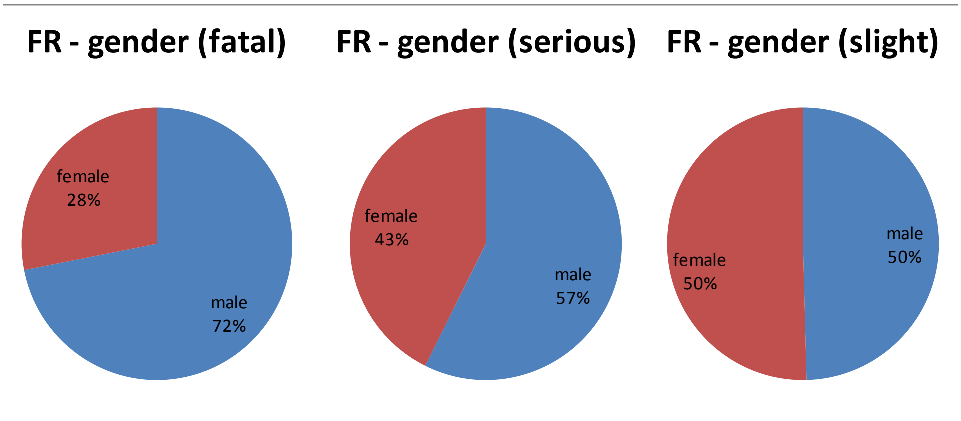


**Figure 4-24. Gender of car occupant casualties in frontal impacts in France, 2008**

Figure 4-25 and Figure 4-26 show the age of the car occupant casualties in frontal impacts in Great Britain and France respectively. The proportions in the two countries are similar, and show how the proportion of older casualties (66+ age group) is higher for fatalities.

When the proportions for all cars and new cars were compared, statistically significant results were found for both countries. The largest differences in Great Britain were an increase in the proportion of fatal casualties aged 12-25 (33.7% in all cars, 37.8% in new cars), and a decrease in the proportion of fatal casualties aged 26-45 (27.0% in all cars, 22.7% in new cars). In France, the largest differences were a decrease in the proportion of fatalities aged 12-25 (29% in all cars, 21% in new cars), and an increase in the proportion of fatalities aged 46-65 (22% in all cars, 28% in new cars).

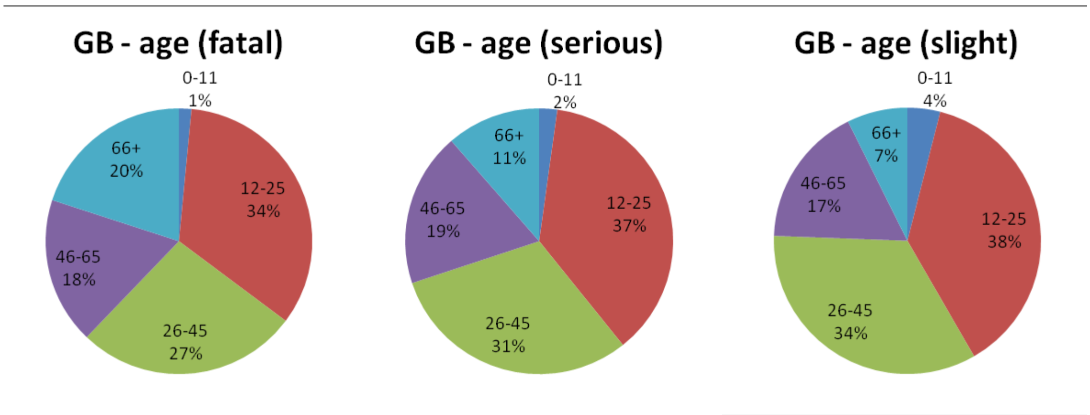


**Figure 4-25. Age of car occupant casualties in frontal impacts in Great Britain, 2008**

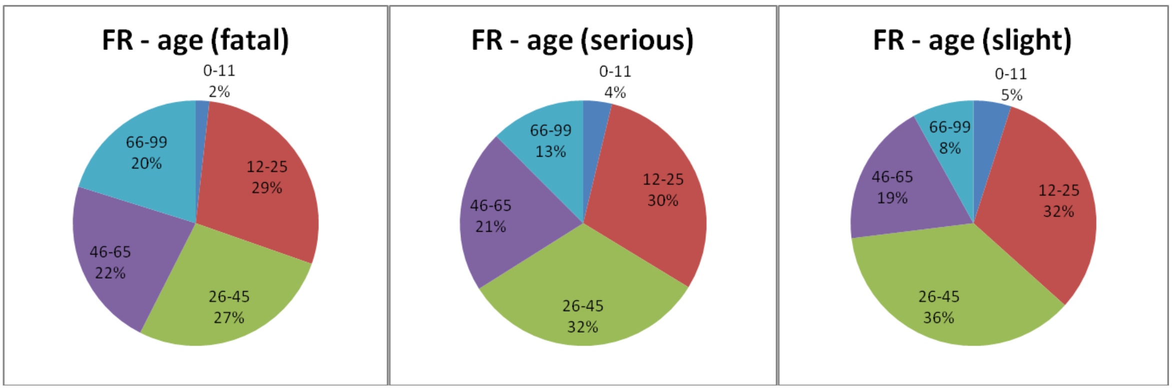


**Figure 4-26. Age of car occupant casualties in frontal impacts in France, 2008**

Table 4-1 and Table 4-2 show the seating position of the car occupant casualties in Great Britain and France respectively. One possible extension of the frontal impact legislation is the inclusion of rear seat passengers, so these tables give the target population in Great Britain and France which could benefit from such a change in the legislation. This shows that 8.6% of fatalities in Great Britain are rear seat passengers, and 10% of fatalities in France are rear seat passengers.

The distribution of seating position was compared in Great Britain and France for all cars and new cars, and no significant differences were found.

**Table 4-1. Seating position of car occupant casualties in frontal impacts in Great Britain, 2008**

| Position | Injury severity | | |
|---|---|---|---|
| | **Fatal** | **Serious** | **Slight** |
| Driver | 526 (72%) | 4730 (67.6%) | 43467 (67.7%) |
| FSP | 142 (19.4%) | 1458 (20.8%) | 13307 (20.7%) |
| RSP | 63 (8.6%) | 807 (11.5%) | 7386 (11.5%) |

**Table 4-2. Seating position of car occupant casualties in frontal impacts in France, 2008**

| Position | Injury severity | | |
|---|---|---|---|
| | Fatal | Serious | Slight |
| Driver | 1064 (76%) | 6826 (69%) | 10397 (68%) |
| FSP | 198 (14%) | 1983 (20%) | 3000 (20%) |
| RSP | 136 (10%) | 1146 (12%) | 1824 (12%) |

It was not possible to investigate the breakdown of casualties by the maximum permitted gross vehicle mass (one potential change to Regulation 94 is to increase the scope to include $M_1$ vehicles >2.5 tonnes and <3.5 tonnes) because the national data did not contain reliable information on maximum vehicle mass.

*4.3.2.3 Effect of fully compliant Regulation 94 car fleet on target population*

This section describes how the target populations from 2008 were adjusted to give an estimate of the size of the target population assuming that all cars in the fleet were compliant with Regulation 94.

The adjusted target population for frontal impacts was calculated as follows:

(1) The total number of casualties (fatal + serious + slight) in frontal impacts remains the same as for 2008.

(2) The proportion of fatal, serious, and slight casualties is adjusted to be the same as for new cars (those registered on 1st October 2003 or later which are compliant with Regulation 94, see section 2).

It should be noted that this method of adjustment is simple and does not take into account confounding factors, for example older people drive newer cars.

Table 4-3 shows the number and proportion of car occupant casualties in frontal impacts in Great Britain, for all cars and cars registered on or after 1st October 2003. Table 4-4 gives the size of the target population in 2008, as well as the size of the adjusted target population for fatal and serious casualties. This shows that the adjusted target population for fatalities in Great Britain is 98% of the number of fatalities which occurred in 2008. The adjusted target population for serious casualties is 90% of the number in 2008.

**Table 4-3. Frontal impacts target population - Great Britain**

| 2008 | All cars | | Cars registered after 1st October 2003 | |
|---|---|---|---|---|
| | **Number** | **Proportion** | **Number** | **Proportion** |
| Fatal | 731 | 1.0% | 242 | 1.0% |
| Serious | 6995 | 9.7% | 2134 | 8.8% |
| Slight | 64176 | 89.3% | 21870 | 90.2% |

**Table 4-4. Adjustment of target population for non- compliant R94 vehicles**

| | Target population | |
|---|---|---|
| | **Adjusted** | **2008** |
| Fatal | 718 (98% of 2008) | 731 |
| Serious | 6328 (90% of 2008) | 6995 |

Table 4-5 shows the number and proportion of car occupant casualties in frontal impacts in France, for all cars and cars registered on or after 1st October 2003. Table 4-6 gives the size of the target population in 2008, as well as the size of the adjusted target population for fatal and serious casualties. This shows that the adjusted target population for fatalities in France is 80% of the number of fatalities which occurred in 2008. The adjusted target population for serious casualties is 89% of the number in 2008.

**Table 4-5. Frontal impacts target population - France**

| 2008 | All cars | | Cars registered after 1st October 2003 | |
|---|---|---|---|---|
| | **Number** | **Proportion** | **Number** | **Proportion** |
| Fatal | 1398 | 5.2% | 270 | 4.2% |
| Serious | 9968 | 37.4% | 2143 | 33.3% |
| Slight | 15278 | 57.3% | 4013 | 62.4% |

**Table 4-6. Adjustment of target population for non- compliant R94 vehicles**

| | Target population | |
|---|---|---|
| | **Adjusted** | **2008** |
| Fatal | 1119 (80% of 2008) | 1398 |
| Serious | 8885 (89% of 2008) | 9968 |

In terms of the numbers of casualties, the size of the frontal impact target population is higher in France than in Great Britain. However, the adjusted value is lower as a proportion of the casualties in 2008 for France compared to Britain. This is because, although the number of casualties in newer cars is greater in France, the reduction in the proportion of fatal and serious casualties is also greater in France. The reasons for this difference are unknown.

### *4.3.3 Safety levels of new cars compared to old cars*

The safety of old and new vehicles was compared by calculating the "severity proportion" for different ages of vehicle. The severity proportion for a given injury severity is defined as the number of casualties of that severity, divided by the total number of casualties. This is one method of comparing different populations to determine which is "safer" than the other, for example whether new cars are safer than old cars.

Table 4-7 shows the fatal proportion for car drivers in a frontal impact by the age of the car containing the fatality. Cars registered in October 2003 or later represent 'new' cars that are Regulation 94 compliant. Cars registered between 1998 and 2003 are cars which may have been Regulation 94 compliant. Cars registered for Oct 1994 to Sept 1998 represent 'old' cars which were registered before the Regulation came into force. This information was available for Great Britain (GB) and France (FR), and the French national data was also able to distinguish between drivers who were and were not wearing a seat belt. The "*" shows where the proportion for that age of vehicle was not significantly different to the age of vehicle which precedes it.

This table shows that the fatal proportion is less for newer cars than for older cars, i.e. it appears that new cars in frontal impacts are safer than old cars in frontal impacts.

**Table 4-7. Fatal proportion for front impacts – car drivers only**

| | **GB** | **DE** | **FR - all** | **FR - belted** |
|---|---|---|---|---|
| Pre Oct 1994 | 0.017 | - | | |
| Oct 1994 – Sep 1998 | 0.012 | - | 0.058 | 0.047 |
| Oct 1998 – Sep 2003 | 0.010 | - | 0.048 | 0.038 |
| Oct 2003 or later | 0.009 | - | 0.044 | 0.038* |
| Unknown | 0.009 | - | | |

*means there is no significant difference between that age of vehicle and the previous age of vehicle ($p > 0.05$)

Table 4-8 shows the fatal proportion for car drivers in front-front, car-car impacts, by the age of the vehicle containing the fatality. This information was available for Great Britain (GB), Germany (DE), and France (FR). This again shows that the fatal proportion for drivers in front-front car-car impacts is lower for new cars than for old cars, i.e. new cars appear to be safer than old cars.

**Table 4-8. Fatal proportion for front-front, car impacts – car drivers only**

| | GB | DE | FR - all | FR - belted |
|---|---|---|---|---|
| Pre Oct 1994 | 0.021 | 0.039 | | |
| Oct 1994 – Sep 1998 | 0.010 | 0.028 | 0.042 | 0.037 |
| Oct 1998 – Sep 2003 | 0.008 | 0.021 | 0.025 | 0.022 |
| Oct 2003 or later | 0.006 | 0.013 | 0.022* | 0.021* |
| Unknown | 0.007 | 0.031 | | |

*means there is no significant difference between that age of vehicle and the previous age of vehicle (p > 0.05)

Table 4-9 shows the KSI proportion for car drivers in a frontal impact by the age of the car containing the fatally or seriously injured driver. In general, this shows that the KSI proportion is lower for new cars. However, in Great Britain there is a small but significant increase in the severity proportion of new cars (registered in October 2003 or later) compared to mid-age cars (registered between October 1998 and September 2003). There is also an increase in severity proportion for belted drivers in France, although this increase is not significant.

**Table 4-9. KSI proportion for front impacts – car drivers only**

| | GB | DE | FR - all | FR - belted |
|---|---|---|---|---|
| Pre Oct 1994 | 0.136 | - | | |
| Oct 1994 – Sep 1998 | 0.109 | - | 0.432 | 0.416 |
| Oct 1998 – Sep 2003 | 0.097 | - | 0.390 | 0.378 |
| Oct 2003 or later | 0.099 | - | 0.394* | 0.389* |
| Unknown | 0.118 | - | | |

*means there is no significant difference between that age of vehicle and the previous age of vehicle (p > 0.05)

Table 4-10 shows the KSI proportion for car drivers in front-front, car-car impacts, by the age of the vehicle containing the fatally or seriously injured driver. In general, this shows that there is a decrease in severity proportion for newer cars. However, similarly to Table 4-9, this shows that there is a significant increase in KSI proportion between mid-age and new cars.

**Table 4-10. KSI proportion for front-front, car impacts – car drivers only**

| | GB | DE | FR - all | FR - belted |
|---|---|---|---|---|
| Pre Oct 1994 | 0.159 | 0.336 | | |
| Oct 1994 – Sep 1998 | 0.115 | 0.292 | 0.423 | 0.420 |
| Oct 1998 – Sep 2003 | 0.100 | 0.265 | 0.347 | 0.347 |
| Oct 2003 or later | 0.096* | 0.228 | 0.368 | 0.371 |
| Unknown | 0.131 | 0.285 | | |

*means there is no significant difference between that age of vehicle and the previous age of vehicle (p > 0.05)

The following tables take into account both the age of the car containing the casualty of interest, and the age of the car which that vehicle has hit. The differences in severity proportion have been tested using a Z-test to determine whether they are statistically significant. The results of these tests are shown for the values on the diagonal, i.e. car-car impacts where both vehicles are from the same age category. An "*" denotes that there is no statistically significant difference between that value and any other on the diagonal. Impacts involving new-new cars (registered in October 2003 or later) and old-old cars (registered between October 1994 and September 1998) have been highlighted in bold, and the severity proportions compared. A "+" denotes that there is no significant difference between these two values.

Table 4-11 shows the fatal proportion for front-front car-car impacts occurring in Great Britain, by the age of the vehicle and its impact partner. There are no significant differences between any of the values on the diagonal.

**Table 4-11. Fatal proportion for front-front, car-car impacts, taking into account registration of partner vehicle – car drivers only, Great Britain**

| | Pre Oct 1994 | Oct 1994 – Sep 1998 | Oct 1998 – Sep 2003 | Oct 2003 or later | Unknown |
|---|---|---|---|---|---|
| Pre Oct 1994 | 0.009* | 0.018 | 0.018 | 0.031 | 0.026 |
| Oct 1994 – Sep 1998 | 0.008 | **0.007*+** | 0.010 | 0.019 | 0.007 |
| Oct 1998 – Sep 2003 | 0.007 | 0.008 | 0.009* | 0.010 | 0.006 |
| Oct 2003 or later | 0.006 | 0.005 | 0.003 | **0.008*+** | 0.007 |
| Unknown | 0.006 | 0.006 | 0.007 | 0.009 | 0.008 |

* Means there is no significant difference between this value and any other value on the diagonal.
+ means there is no significant differences between the values in bold.

Table 4-12 shows the KSI proportion for front-front car-car impacts occurring in Great Britain, by the age of the vehicle and its impact partner. The differences on the diagonal are significant, including the difference between old-old car impacts and new-new car impacts (the values in bold). This shows that the proportion of drivers killed or seriously injured in impacts involving new-new cars is higher than the proportion in old-old cars.

**Table 4-12. KSI proportion for front-front, car-car impacts, taking into account registration of partner vehicle – car drivers only, Great Britain**

| | Pre Oct 1994 | Oct 1994 – Sep 1998 | Oct 1998 – Sep 2003 | Oct 2003 or later | Unknown |
|---|---|---|---|---|---|
| Pre Oct 1994 | *0.136* | 0.161 | 0.155 | 0.195 | 0.154 |
| Oct 1994 – Sep 1998 | 0.099 | ***0.095*** | 0.121 | 0.142 | 0.111 |
| Oct 1998 – Sep 2003 | 0.085 | 0.091 | *0.103* | 0.118 | 0.097 |
| Oct 2003 or later | 0.084 | 0.095 | 0.087 | ***0.114*** | 0.096 |
| Unknown | 0.113 | 0.122 | 0.123 | 0.153 | 0.135 |

* Means there is no significant difference between this value and any other value on the diagonal.
+ means there is no significant differences between the values in bold.

Table 4-13 shows the fatal proportion for front-front car-car impacts occurring in Germany, by the age of the vehicle and its impact partner. The differences between old-old car impacts and new-new car impacts are significant, and show an increase in the fatal proportion from 0.022 for old-old car impacts to 0.033 for new car impacts.

**Table 4-13. Fatal proportion for front-front, car-car impacts, taking into account registration of partner vehicle – car drivers only, Germany**

| | Pre Oct 1994 | Oct 1994 – Sep 1998 | Oct 1998 – Sep 2003 | Oct 2003 or later | Unknown |
|---|---|---|---|---|---|
| Pre Oct 1994 | *0.028* | 0.034 | 0.048 | 0.055 | |
| Oct 1994 – Sep 1998 | 0.013 | ***0.022*** | 0.037 | 0.047 | |
| Oct 1998 – Sep 2003 | 0.013 | 0.016 | *0.027* | 0.031 | |
| Oct 2003 or later | 0.003 | 0.009 | 0.012 | ***0.033*** | |
| Unknown | | | | | |

* Means there is no significant difference between this value and any other value on the diagonal.
+ means there is no significant differences between the values in bold.

Table 4-14 shows the KSI proportion for front-front car-car impacts occurring in Germany, by the age of the vehicle and its impact partner. The differences between old-old and new-new car impacts are not significant.

**Table 4-14. KSI proportion for front-front, car-car impacts, taking into account registration of partner vehicle – car drivers only, Germany**

| | Pre Oct 1994 | Oct 1994 – Sep 1998 | Oct 1998 – Sep 2003 | Oct 2003 or later | Unknown |
|---|---|---|---|---|---|
| Pre Oct 1994 | | | | | |
| Oct 1994 – Sep 1998 | | ***0.280***+* | 0.324 | 0.355 | |
| Oct 1998 – Sep 2003 | | 0.255 | *0.289* | 0.304 | |
| Oct 2003 or later | | 0.234 | 0.246 | ***0.272**+* | |
| Unknown | | | | | |

* Means there is no significant difference between this value and any other value on the diagonal.
+ means there is no significant differences between the values in bold.

Table 4-15 shows the fatal proportion for front-front car-car impacts occurring in France, by the age of the vehicle and its impact partner. There are no significant differences on the diagonal.

**Table 4-15. Fatal proportion for front-front, car-car impacts, taking into account registration of partner vehicle – car drivers only, France**

| | Pre Oct 1994 | Oct 1994 – Sep 1998 | Oct 1998 – Sep 2003 | Oct 2003 or later | Unknown |
|---|---|---|---|---|---|
| Pre Oct 1994 | *0.033** | 0.062 | 0.062 | 0.071 | |
| Oct 1994 – Sep 1998 | 0.031 | ***0.032***+* | 0.049 | 0.060 | |
| Oct 1998 – Sep 2003 | 0.017 | 0.019 | *0.029** | 0.039 | |
| Oct 2003 or later | 0.012 | 0.015 | 0.024 | ***0.032***+* | |
| Unknown | 0.028 | 0.053 | 0.068 | 0.105 | |

* Means there is no significant difference between this value and any other value on the diagonal.
+ means there is no significant differences between the values in bold.

Table 4-16 shows the KSI proportion for front-front car-car impacts occurring in France, by the age of the vehicle and its impact partner. There are no significant differences between the KSI proportion in old-old car impacts compared to new-new car impacts (the values in bold).

**Table 4-16. KSI proportion for front-front, car-car impacts, taking into account registration of partner vehicle – car drivers only, France**

| | Pre Oct 1994 | Oct 1994 – Sep 1998 | Oct 1998 – Sep 2003 | Oct 2003 or later | Unknown |
|---|---|---|---|---|---|
| Pre Oct 1994 | *0.432** | 0.468 | 0.471 | 0.491 | |
| Oct 1994 – Sep 1998 | 0.373 | ***0.414+*** | 0.436 | 0.471 | |
| Oct 1998 – Sep 2003 | 0.314 | 0.345 | *0.338* | 0.389 | |
| Oct 2003 or later | 0.315 | 0.355 | 0.362 | ***0.417+*** | |
| Unknown | 0.500 | 0.579 | 0.551 | 0.632 | |

* Means there is no significant difference between this value and any other value on the diagonal.
+ means there is no significant differences between the values in bold.

Table 4-17 shows the fatal proportion for front-front car-car impacts occurring in France, for drivers wearing seat belts, by the age of the vehicle and its impact partner. There are no significant differences between old-old car impacts and new-new car impacts (the values in bold). However, there is a significant increase in the fatal proportion between cars registered in 1998-2003, and those registered in 2003 or later.

**Table 4-17. Fatal proportion for front-front, car-car impacts, taking into account registration of partner vehicle – seat belted car drivers only, France**

| | Pre Oct 1994 | Oct 1994 – Sep 1998 | Oct 1998 – Sep 2003 | Oct 2003 or later | Unknown |
|---|---|---|---|---|---|
| Pre Oct 1994 | *0.028** | 0.057 | 0.052 | 0.061 | |
| Oct 1994 – Sep 1998 | 0.028 | ***0.025*+*** | 0.045 | 0.052 | |
| Oct 1998 – Sep 2003 | 0.014 | 0.019 | *0.024* | 0.036 | |
| Oct 2003 or later | 0.011 | 0.016 | 0.022 | ***0.032+*** | |
| Unknown | 0.025 | 0.060 | 0.065 | 0.075 | |

* Means there is no significant difference between this value and any other value on the diagonal.
+ means there is no significant differences between the values in bold.

Table 4-18 shows the KSI proportion for front-front car-car impacts occurring in France, for drivers wearing seat belts, by the age of the vehicle and its impact partner. There are no significant differences between the values in bold. However, there is a significant increase in the fatal proportion between cars registered in 1998-2003, and those registered in 2003 or later.

**Table 4-18. KSI proportion for front-front, car-car impacts, taking into account registration of partner vehicle – seat belted car drivers only, France**

| | Pre Oct 1994 | Oct 1994 – Sep 1998 | Oct 1998 – Sep 2003 | Oct 2003 or later | Unknown |
|---|---|---|---|---|---|
| Pre Oct 1994 | *0.425** | 0.461 | 0.460 | 0.480 | |
| Oct 1994 – Sep 1998 | 0.365 | ***0.413+*** | 0.436 | 0.465 | |
| Oct 1998 – Sep 2003 | 0.311 | 0.350 | *0.335* | 0.391 | |
| Oct 2003 or later | 0.317 | 0.368 | 0.366 | ***0.414+*** | |
| Unknown | 0.471 | 0.583 | 0.553 | 0.625 | |

## 4.4 Summary of findings and regulatory implications

### *4.4.1 Changes over time*

- Over the period 1998 – 2007 road accident fatalities in the EU27 have reduced by approximately 30% from 58,982 to 42,854.
- National data from Great Britain, Germany, and France indicate that car occupant fatalities form approximately half of all road accident fatalities and have reduced roughly in proportion with all road accident fatalities.
    - Fatality reduction in Germany and France is substantially higher than in Great Britain (26% in Great Britain, 50% in Germany, 62% in France). However Great Britain has the lowest number of fatalities per head of population.
- In summary, road accident fatalities and in particular car occupant fatalities have reduced by approximately 30% since 1998 following the introduction of measures to improve car occupant safety such as the frontal and side impact directives / regulations and Euro NCAP. However, based on accident data from GB, France and Germany car occupant fatalities still account for about half of all road accident fatalities (EU27 in 2007: 42,854) and hence remain a substantial problem.

### *4.4.2 Target population*

- National data from Great Britain, Germany, and France indicate that car occupant fatalities form approximately half of all road accident fatalities. Car frontal impacts account for between 59-63% of car fatalities (731 in Great Britain, 1398 in France). This illustrates the substantial size of the target population for potential changes to Regulation 94 (EU27 in 2007: 42,854*0.5*0.6 = 12,856).
    - Car-to-car frontal impacts account for between 16-22% of car fatalities (271 in Great Britain, 353 in France). Note: this does not include accidents involving 3 or more vehicles, so percentage will be higher when this is taken into account.
- Drivers make up 72-76% of frontal impact fatalities in GB and France. Front seat passengers make up 14-19% of fatalities, and rear seat occupants make up 9-10% of fatalities. This gives the target population that could be affected by extending the Regulation to include protection of rear seat passengers.
- In Great Britain and France, elderly occupants (aged 66 or over) make up 20% of car fatalities in frontal impacts. This indicates that elderly occupants have a

higher risk of a fatal injury and because demographically the proportion of older people in Europe is growing, it is suggested that future potential changes to Regulation 94 should consider older occupants. However, it should be noted that the largest proportion of fatalities are aged 12-25 years, which account for 34% of fatalities in Great Britain and 29% in France.

- In Great Britain, France and Germany the majority (74-79%) of car occupant fatalities occur in accidents on rural roads as opposed to urban roads or motorways.
- The adjustments to the 2008 frontal impact casualty figures, to estimate the number of casualties once all cars are compliant with Regulation 94, are as follows:
    - Great Britain: 98% of fatalities, 90% of serious casualties
    - France: 80% of fatalities, 89% of serious casualties

  This suggests that, although the number of fatalities and serious injuries may be reduced once the entire fleet is Regulation 94 compliant, there will still be a significant number of deaths and serious injuries in frontal impacts.
- The number of $N_1$ (LGV) fatalities (<2% of all road fatalities) is low in Great Britain, France and Germany compared with $M_1$ casualties (~50% of road fatalities). This gives an approximate size for the target population of casualties which could be affected by extending the scope of Regulation 94 to include $N_1$ vehicles. However, a small target population alone does not indicate that such a scope change should not be considered further. This is because the number of $N_1$ vehicles compared to cars on European roads is also low which indicates that the total cost to modify them to be compliant with Regulation 94 may also be low, which in turn indicates that the cost to benefit ratio for this potential change to Regulation 94 could be better than for other potential changes for cars.
- At present the rear seat occupant position is not tested in Regulation 94. Based on data from Great Britain and France, the proportion of car occupant fatalities seated in the rear is small (9-10%) which indicates that the target population for a potential change to the Regulation is also small. However, as above this alone does not indicate that such a change should not be considered further.

#### 4.4.3 Safety levels of new cars compared to old cars

- An investigation of the effect of vehicle age on its safety performance was performed by comparing the severity proportion of casualties in different aged vehicles using national data from the GB, Germany and France for the years 2005 to 2008 inclusive. The severity proportion is defined as the number of casualties of that severity, divided by the total number of casualties. The study found that for all frontal impacts and the subset of frontal car-to-car impacts when the age of the partner car is not taken into account the severity proportion for fatalities and KSI is significantly lower for new cars ($1^{st}$ Oct 2003+) compared to old cars (1994-1998). This indicates that newer cars are ‘safer’ than older cars.
    - However, there was a significant increase in KSI proportion between new cars ($1^{st}$ Oct 2003+) and mid-age cars (1998-2003) in Great Britain for all frontal impacts, and in France for all frontal impacts and belted drivers in car-car impacts.
- For car-to-car frontal impacts, when the age of the partner was vehicle taken into account, there were indications of some increases in severity proportion for new-new ($1^{st}$ Oct 2003+) cars compared to old-old cars (1994-1998). This increase is seen in Germany for fatalities and in Great Britain for KSI. These increases in severity proportion are a possible indication that safety in car-to-car impacts has not improved; however there are many confounding factors which have not been

taken into account in this analysis which could be affecting the results, such as type of driver, mass of vehicle, type of vehicle, driver age and gender, and impact severity.

# 5 Task 2: Determination of detailed frontal impact taxonomy using detailed accident databases

## 5.1 Introduction

The objective of this task was to perform an analysis of detailed accident databases to continue the development of the taxonomy of frontal impacts and quantification of target populations for potential changes to frontal impact legislation started in Task 1.

The proportions of frontal impact casualties in accidents with different impact partners, overlaps, collision severities, and other factors were identified. This allowed the identification of the size of the frontal impact target populations in terms of casualty frequency and severity. The injury types and mechanisms of injury in frontal impacts were also investigated. The analysis was performed using Regulation 94 compliant (or equivalent) vehicles only to ensure that the results were representative of the performance of Regulation 94 compliant vehicles and hence appropriate for use to set priorities for the update of Regulation 94.

In addition to looking at Regulation 94 compliant (or equivalent) cars, an investigation of the characteristics of $N_1$ vehicles, which are not included within the scope of the current frontal impact legislation, was also performed. $M_1$ vehicles with a maximum permitted weight above 2.5 tonnes are also not included in the legislation, but were not analysed because they could not be identified in the in-depth accident data.

## 5.2 Description of work

The work in this task was split into a number of parts. The first part refined the estimate of the target populations determined in Task 1 using the additional information available in the detailed accident databases. This involved the identification of casualties who would not be likely to benefit from potential changes to the Regulation because, for example, they were not wearing their seatbelt, and then removing them from the target population.

The second part used the in-depth accident data to determine detailed characteristics of the accident configurations, occupants, injuries, and injury mechanisms for frontal impacts.

The third part summarised the results from the second part in terms of target populations. For example, to help consider the magnitude of the possible effect of a potential change to Regulation 94 to introduce a full width test, the number of MAIS 2 injured casualties who were involved in a high overlap accident in which two of the car’s main longitudinal rails were loaded was expressed as a proportion of all MAIS 2 injured casualties in car frontal impacts. Similarly, the proportions of MAIS 3+ and fatally injured occupants who were involved in a high overlap accident were expressed in this way.

Finally, the fourth part of this work investigated $N_1$ vehicles, and compared the characteristics of impacts with these vehicles to those for $M_1$ vehicles.

### *5.2.1 Identification of target populations for car occupant casualties in frontal impacts*

In this part of the work the target populations which were identified in section 4.3.2 were refined using the information available in the detailed accident data. This involved the identification of casualties who would not be likely to benefit from potential changes to the Regulation and then removing them from the target population. Casualties identified and removed from the target population were those not wearing a seatbelt, those seated in front of an occupant who was not wearing a seatbelt and those involved in an accident in which the vehicle rolled over.

The refined target populations were compared to see how the proportions of impact partner, severity, and occupants removed from the sample differ in Great Britain, Germany, and France. After this point in the analysis, only data from Great Britain and Germany was used because the number of Regulation 94 compliant (or equivalent) vehicles in the French in-depth data was not sufficient for further analysis.

The target populations were then scaled to the national population of accidents in Great Britain and in Germany, and were broken down by injury severity (fatal and serious) and maximum abbreviated injury score (MAIS 2 survived and MAIS 3+ survived). This enabled the results from the detailed analysis to be scaled to the national level.

### *5.2.2 Detailed accident analysis for car occupants*

For the casualties within the refined target populations, the in-depth accident data from Great Britain and Germany was used to investigate the proportion of these casualties who have particular characteristics. The analysis was performed for the different groups (e.g. drivers in car-car/LGV impacts, front row occupants in car-wide object impacts etc.) partly to see how these groups differed from one another, and partly so that the results could be scaled to represent the national population. Some groups were combined, for example rear seat passengers in all types of impact have been combined into one group, so that the sample size was large enough for the results to be meaningful.

The results for drivers in car-car/LGV impacts in Great Britain are shown in section 5.3.2.1, and the results for drivers and front seat passengers in car-car/LGV impacts in Germany are shown in section 5.3.2.2. The results for the other groups of the refined target populations which were large enough to analyse are shown in Appendix B. Differences between these groups and the drivers in car-car/LGV impacts are highlighted, as are differences between Great Britain and Germany. Direct comparisons of the results from Great Britain and Germany are shown in Appendix C.

The first findings presented are related to the characteristics of the impact, such as the principle direction of force, longitudinal loading, overlap, and impact severity. These are factors which are directly related to the set-up of any impact test, so the results from this section (once they have been scaled in terms of the target population) can be used to inform any potential alterations to the test set-up.

The next findings presented are the characteristics of the casualties (such as age and gender), their injuries (by body region), and their injury mechanisms (looking at contact, intrusion, and restraint systems). These are factors which are important when considering the characteristics of the test dummies that should be used in each seating position, and the injuries and injury mechanisms which they should be capable of measuring.

### *5.2.3 Summarising results in terms of the target populations for car occupants*

This section combines the analysis of the target populations, and the in-depth analysis of the impact characteristics, to estimate the proportion of the frontal impact target population which has certain characteristics. This helps to enable the potential effect of regulatory changes to be quantified, for example what proportion of frontal impact casualties would be affected if a full width test was introduced.

The results from the in-depth analysis were scaled using the national data. This scaling was important because CCIS is not representative of the accidents which occur nationally, for example the CCIS sample includes a higher proportion of fatal and seriously injured casualties (the representativeness of CCIS is discussed more detail in

Appendix A). Scaling the results enabled differences in severity and object hit to be taken into account, so the relationship between the in-depth data and the target populations represents the national relationship as closely as is practicable.

#### 5.2.4 $N_1$ vehicles

One way of altering the current frontal impact legislation would be to extend the scope to include other types of vehicles. Currently passenger cars ($M_1$ vehicles) with a maximum permitted gross weight above 2.5 tonnes and light goods vehicles (LGVs, or $N_1$ vehicles) are not within the scope of Regulation 94.

The characteristics of $N_1$ vehicle frontal impacts were explored using the Heavy Vehicle Crash Injury Study fatals database for Great Britain. This shows the characteristics of the impacts and fatalities in these vehicles. Because the maximum permitted gross weight is not recorded as standard in the in-depth databases, the characteristics of impacts involving $M_1$ vehicles above 2.5 tonnes could not be explored.

## 5.3 Findings

#### 5.3.1 Identification of target populations for car occupant casualties in frontal impacts

Figure 5-1 shows the size of the frontal impact target populations in Great Britain by injury severity. These pie charts were created by scaling the results from CCIS using the national STATS19 data. Each pie chart represents all frontal impact casualties of that severity, in all seating positions. The segments in the chart show the proportion of casualties in different impact types, and the proportion who were removed from the target populations and further analysis because they were unbelted, seated in front of an unbelted occupant, or in a vehicle which rolled over.

Figure 5-2 shows the size of the target populations in Germany, created using GIDAS and the national German accident data.

Figure 5-3 shows the size of the target populations in France. Unlike the other two countries these have been calculated using only the French national accident data. This is possible because seat belt use is recorded in this database.

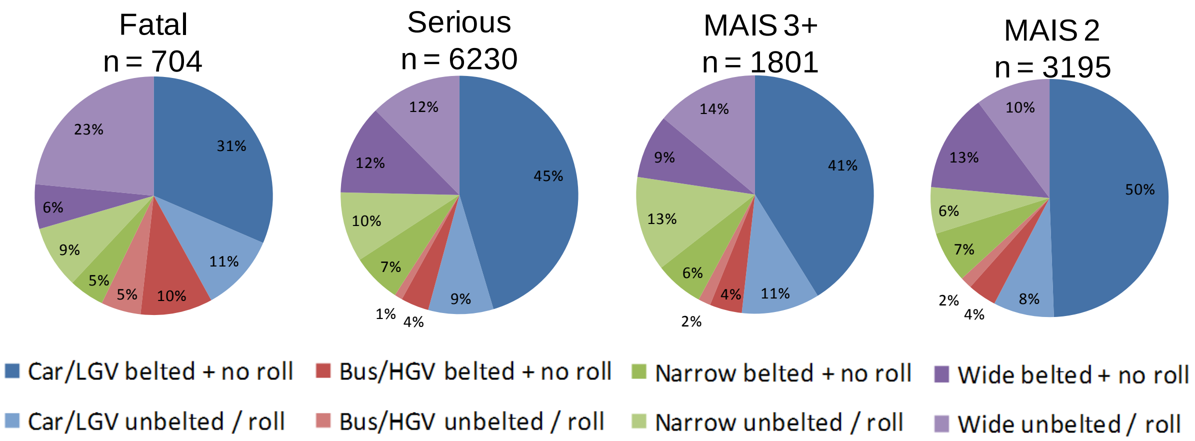


**Figure 5-1. Size of target populations in Great Britain**

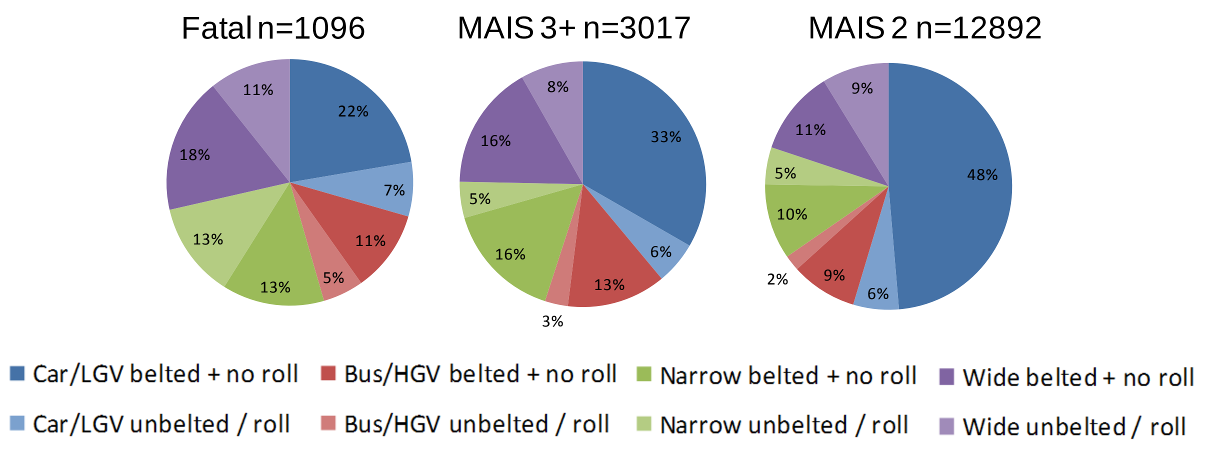


**Figure 5-2. Size of target populations in Germany**

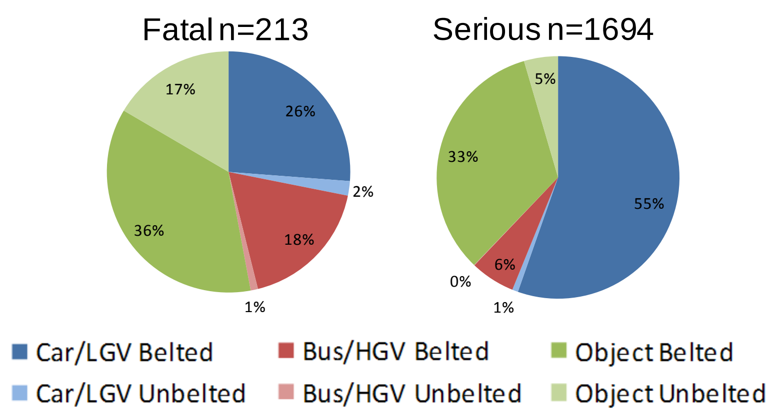


**Figure 5-3. Size of target populations in France**

The figures for Great Britain and Germany again highlight the large number of occupants excluded from the sample because of seat belt use or rollover. This is a particular issue for impacts with wide objects. Looking at these impacts in more detail, it was seen that a combination of low seat belt use and high frequency of rollovers of cars accounts for this.

In contrast, there were very few occupants excluded from the French sample because they were unbelted. This is likely to be because this information comes from the national data, where the police are less likely to record that someone was not wearing a seat belt.

Figure 5-4 shows the initial breakdown of frontal impact target populations which were estimated using the national and in-depth accident data from Great Britain. Figure 5-5 shows the initial breakdown which was estimated using the national and in-depth accident data from Germany.

In these diagrams, the information present in the in-depth accident data has been used to estimate the proportion of each impact type (car-car/LGV, car-HGV/bus, car-narrow object, car-wide object) which would be excluded from the target population because a rollover occurred, the occupant in question was unbelted, or was sitting in front of an occupant who was unbelted.

CCIS records injury in terms of "fatal, serious, slight" to match the national accident data, and also records injury severity using the maximum abbreviated injury score, or MAIS. Because both measures of injury severity are recorded, this allows the analysis to be performed in terms of the more detailed MAIS, and the results can still be scaled to the national level.

GIDAS does not include the "fatal, serious, slight" definitions of injury severity. However, the relationship between GIDAS and the national accident population is known, so the results can still be scaled.

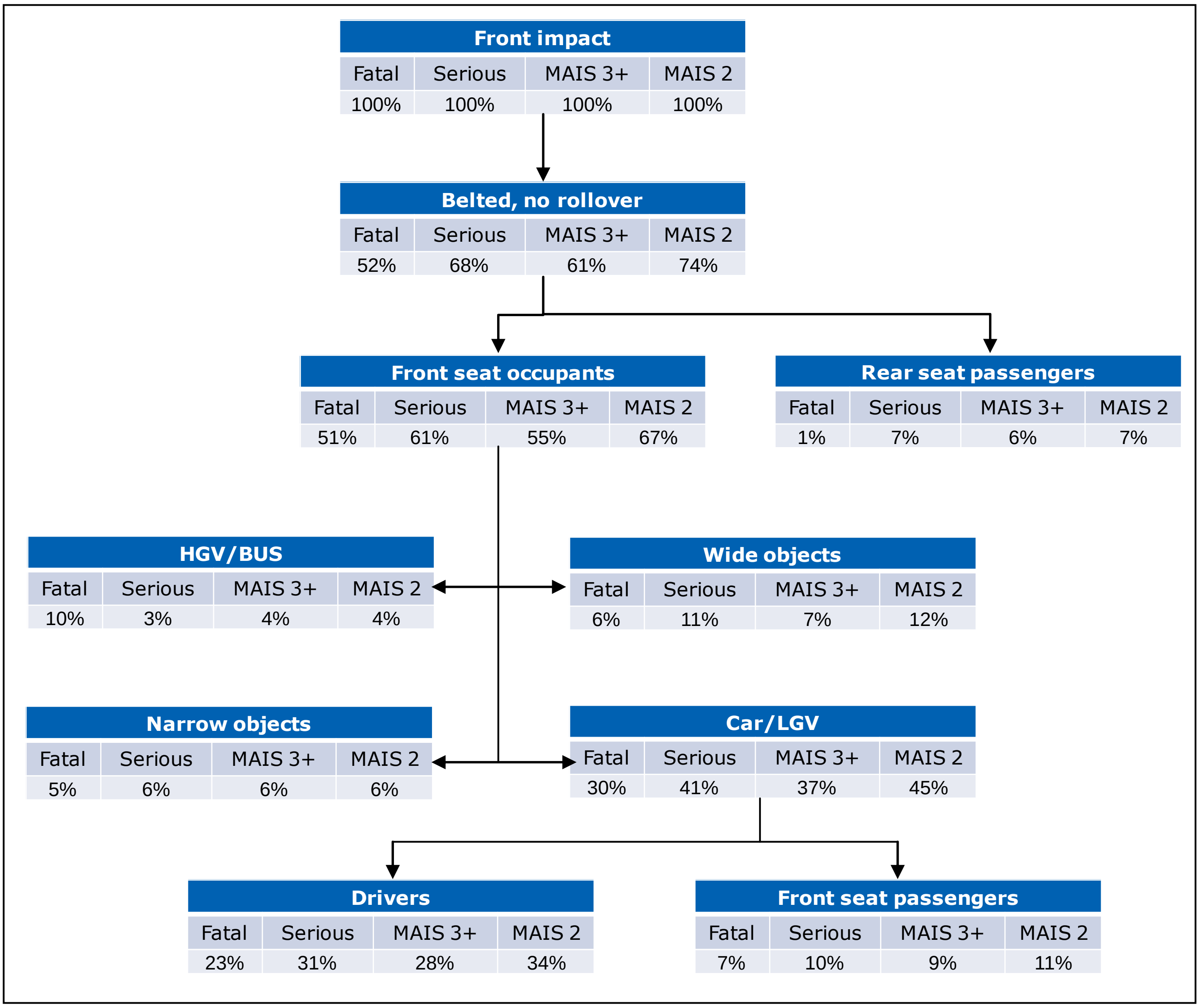


**Figure 5-4. Breakdown of target populations in Great Britain**

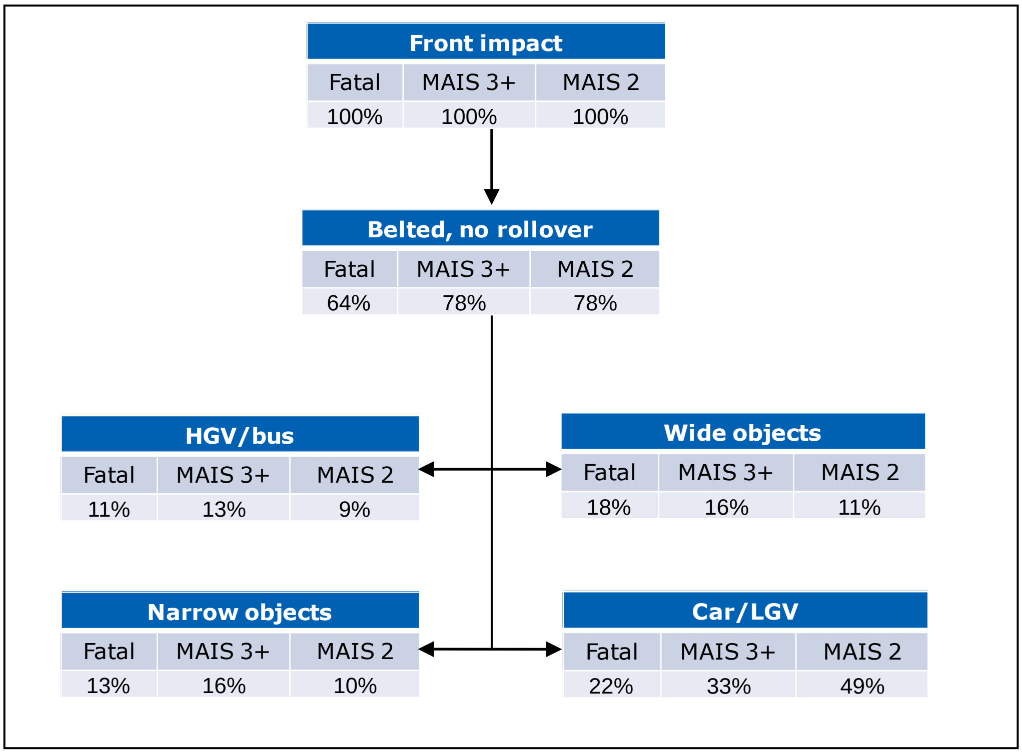


**Figure 5-5. Breakdown of target populations in Germany**

These two figures highlight the large number of occupants who were excluded from the target population because they were not seat belted, had an unbelted occupant behind them, or were in a vehicle which rolled over, and hence would not likely benefit from potential changes to Regulation 94.

These target population diagrams enable the results of the in-depth analysis to be scaled to the national level. The in-depth analysis investigated certain sub-sets of these populations, such as car drivers in impacts with cars/LGVs (after removing those who were unbelted, in rollovers etc.). If, for example, it was found from the in-depth data that 80% of these fatally injured car drivers receive AIS 2+ thorax injuries, Figure 5-4 can be used to calculate what proportion this would be of *all* fatally injured frontal impact casualties. The figure shows that the size of that subset as a proportion of all frontal impact casualties is 23%. Therefore fatally injured car drivers with AIS 2+ thorax injuries, in impacts with cars/LGVs, who were seat belted and whose vehicle did not rollover, account for 80% x 23% = 18% of all fatally injured frontal impact casualties.

Using this method, the detailed accident analysis in section 5.3.2 was combined with the breakdown of target populations to determine the results as a proportion of the total frontal impact target population. These results are shown in the tables in section 5.3.3.

#### *5.3.1.1 Seat belt usage rate of casualties and seating position*

Figure 5-6 shows the seat belt usage rates in the different seating positions, by gender and injury severity. This shows that the seat belt usage rates of rear seat passengers are substantially lower than other car occupants, particularly for fatalities in the rear. This means that the target population of rear seat passengers who could benefit from frontal impact regulation is very small, because it is assumed that unbelted occupants would receive no benefit from any changes in the Regulation.

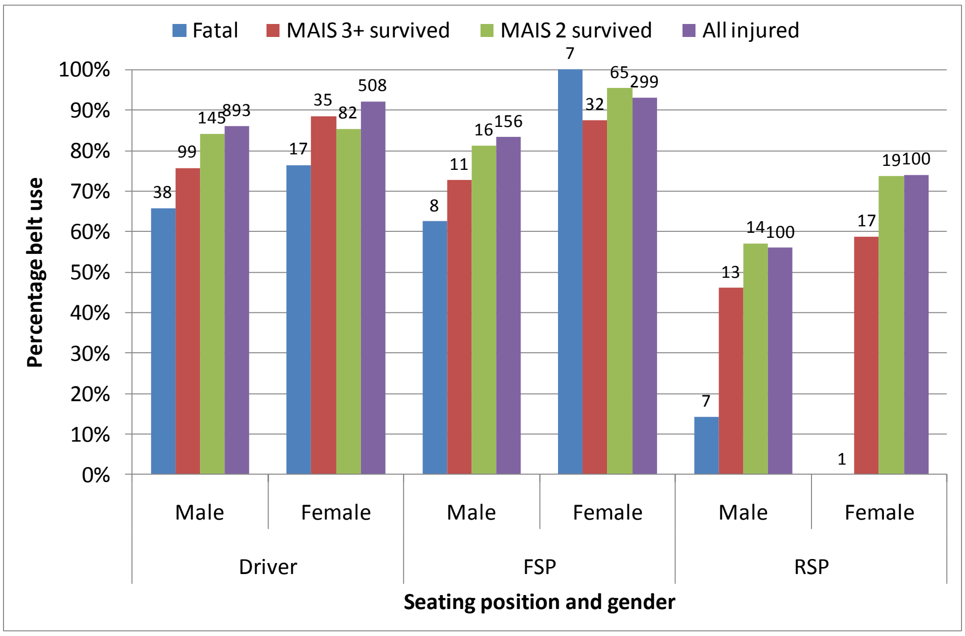


**Figure 5-6. Seat belt use by seating position and gender in all frontal impacts, Great Britain**

### *5.3.2 Detailed accident analysis for car occupants*

This section contains analysis of the in-depth accident data from Great Britain and Germany. It has been performed separately for different subsets of data as shown in Table 5-1, which shows the location in this report of the results from each subset.

**Table 5-1. In-depth analysis of target populations included in this report**

| Population subset | | | Location in report |
|---|---|---|---|
| **Country** | **Impact type** | **Seating position** | |
| Great Britain | Car-car/LGV | Drivers | Section 5.3.2.1 |
| Germany | Car-car/LGV | Drivers and front seat passengers | Section 5.3.2.2 |
| Great Britain | Car-car/LGV | Front seat passengers | Section B.1 |
| Great Britain | Car-all | Rear seat passengers | Section B.2 |
| Great Britain | Car-HGV/bus | Drivers and front seat passengers | Section B.3 |
| Great Britain | Car-wide object | Drivers and front seat passengers | Section B.4 |
| Great Britain | Car-narrow object | Drivers and front seat passengers | Section B.5 |

The results from all of these subsets are summarised in section 5.3.3.

#### *5.3.2.1 Drivers in car-car/LGV impacts in Great Britain*

The majority of impacts were 12 o'clock as shown in Figure 5-7. A larger proportion were 1 o'clock than 11 o'clock. Impacts with a direction of force of 1 o'clock tend to be on the driver's side of the vehicle.

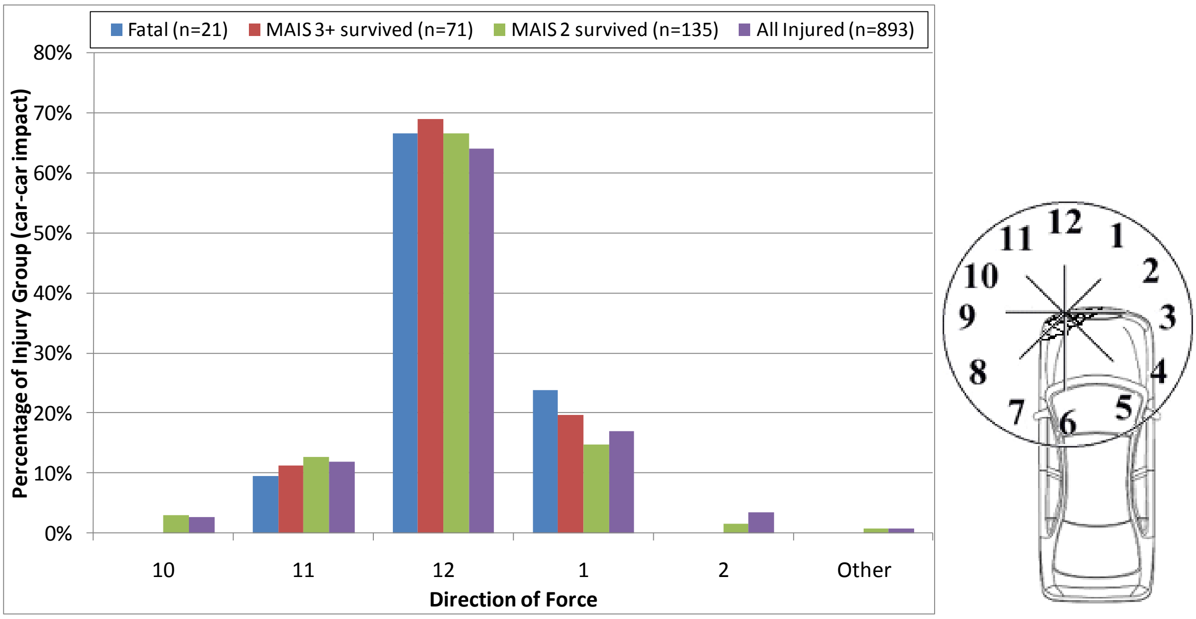


**Figure 5-7. Principal direction of force as a percentage of injury group for drivers in car-car/LGV impacts in GB**

Figure 5-8 shows the vehicle overlap for cars in car to car/LGV impacts in GB as a percentage of the injury group of the driver of that car. This figure shows that a large proportion of impacts have a large overlap (>90%). This suggests that a full overlap test could affect a large proportion of casualties.

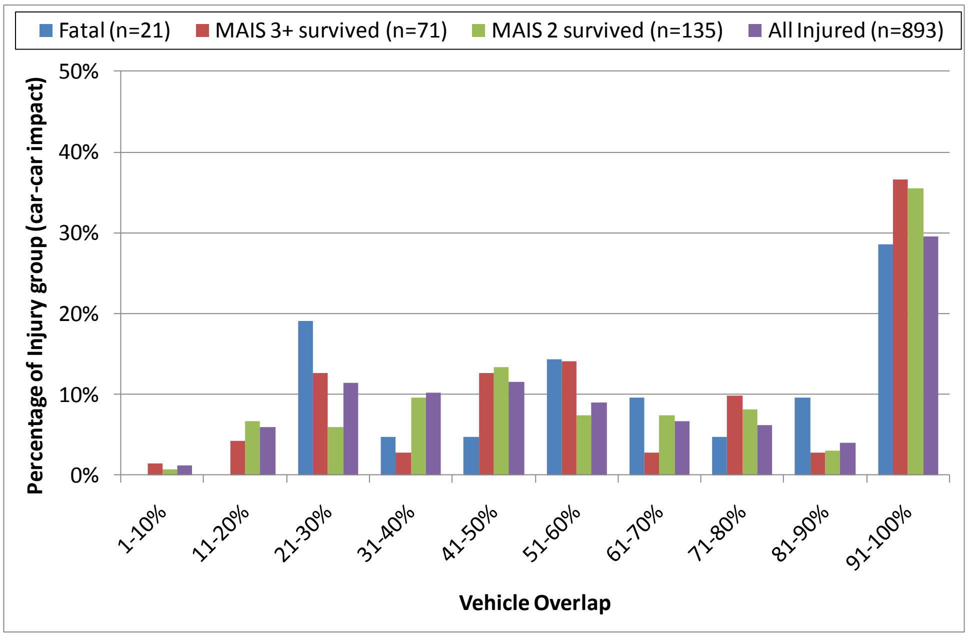


**Figure 5-8. Vehicle overlap as a percentage of injury group in GB for drivers in car-car/LGV impacts in GB**

Figure 5-9 shows the longitudinal loading of the cars that struck cars/LGVs. Offside is defined as the side of the car furthest from the kerb when driving, and is the driver side in a right hand drive car. A large proportion of impacts have both longitudinals directly loaded, which aligns with the findings of Figure 5-8 of the high proportion of >90% overlap. In impacts with HGVs/buses (shown in Appendix B) there is a much higher proportion of impacts with no direct loading to either longitudinal, because the cars have underrun the other vehicle. The current Regulation 94 test is an offset impact, so these results suggest the increase in the proportion of impacts covered by the Regulation if it was altered to include low overlap or full width impacts.

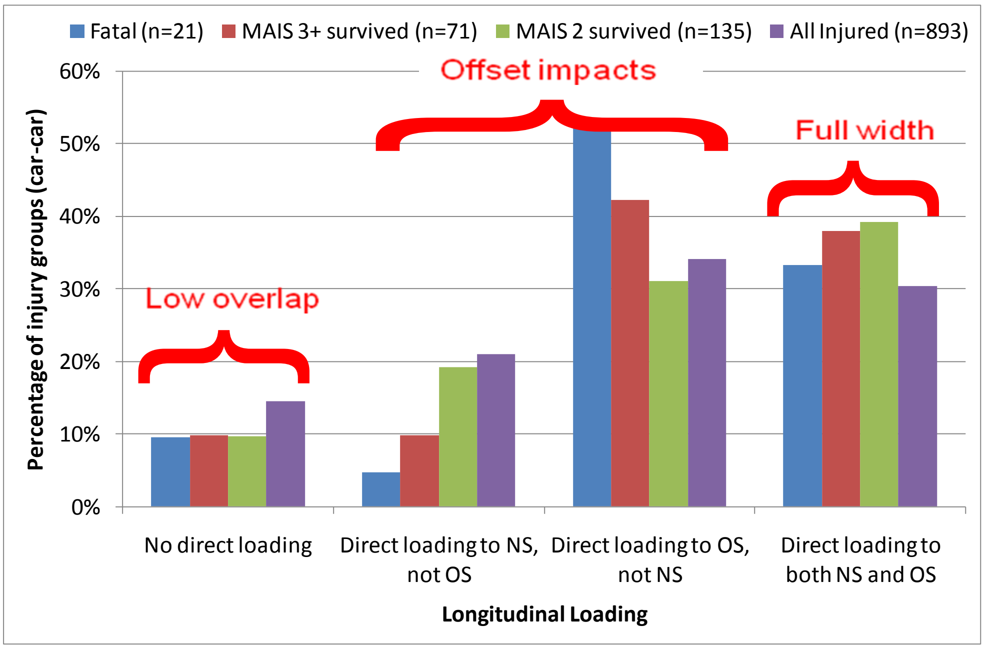


**Figure 5-9. Longitudinal loading as a percentage of injury group for drivers in car-car/LGV impacts in GB**

Figure 5-10 shows that 39% of fatalities were in impacts of 50kph or less, and 90% of MAIS 2 surviving casualties. Of fatalities, 45% were in impacts of 56kph or less and 96% of MAIS 2. This figure also shows that there are some fatalities which occur at relatively low speeds. Of the six fatalities which occurred at an EES under 45 kph, five of them were elderly, aged between 67 and 85 years.

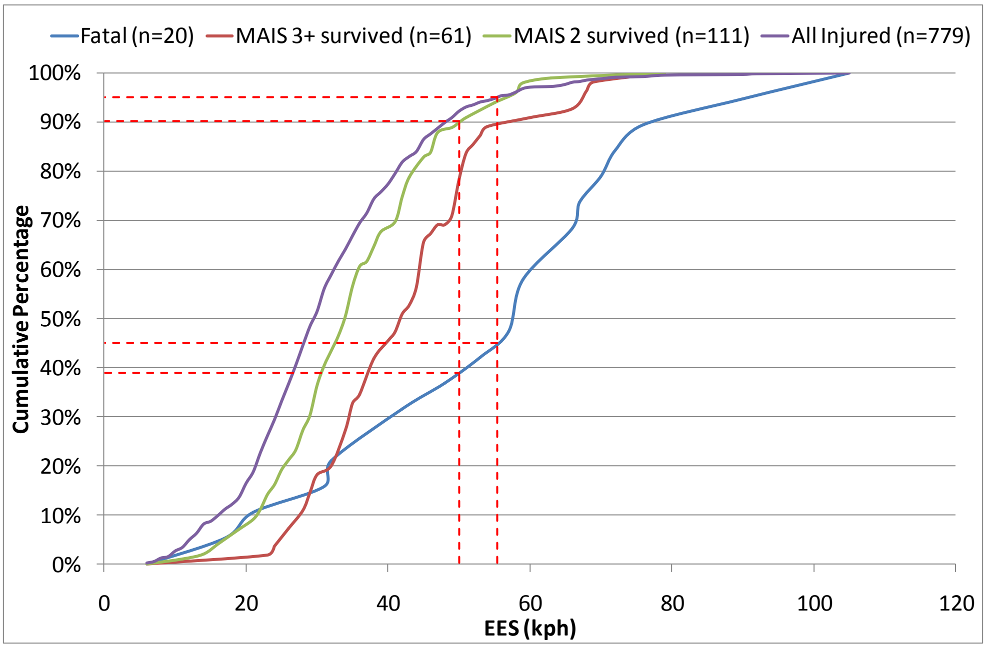


**Figure 5-10. Cumulative percentage of EES for drivers in car-car/LGV impacts in GB**

Some of the variables explored above can be used to determine the proportion of drivers who were in impacts covered by the regulatory test. This is shown in Figure 5-11. Impacts covered by the regulatory test were defined as follows:

- Only one longitudinal directly loaded
- Overlap >=20% and <=70%
- Direction of force = 11, 12, or 1 o'clock
- Severity in terms of Equivalent Energy Speed (EES) = 0-56 kph. (Note: It is recognised that the impact severity covered by the Regulation test lies somewhere between 50 and 56 kph, so 56 kph is a high estimate).

The figure shows that just under 35% of driver casualties occur in impacts covered by the test. For fatalities this percentage is less, about 20%.

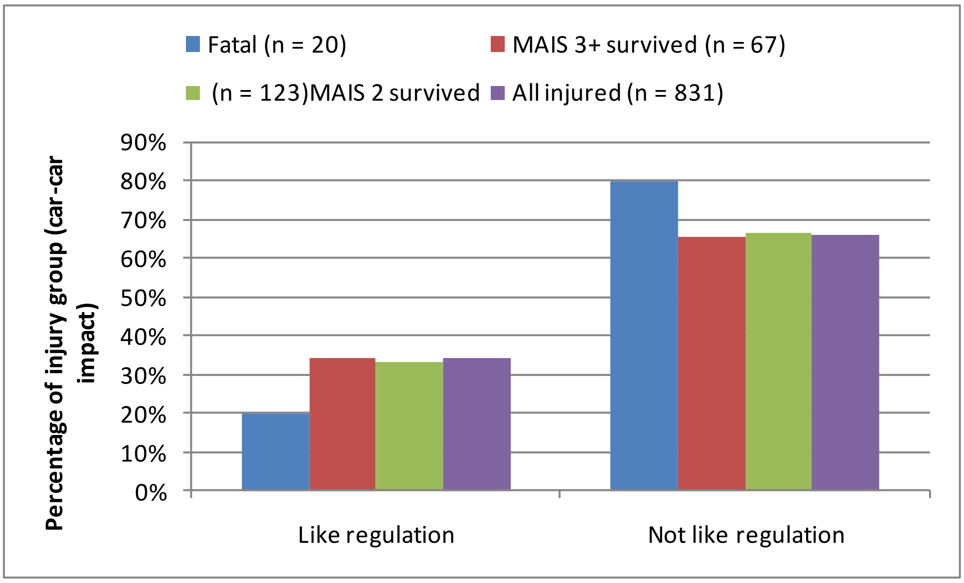


**Figure 5-11. Proportion of drivers in impacts covered by the regulatory test, for car-car/LGV impacts in GB**

Figure 5-12 shows a large proportion of fatalities had intrusion of 10cm or greater. As expected, intrusion was also found to be related to higher speed crashes. The relationship between intrusion and the impact configuration was also explored, but no evidence was found that intrusion was related to the amount of overlap, or the number of longitudinals which were directly loaded. However, the number of vehicles with greater than 10cm of intrusion was relatively small, making it difficult to see significant relationships.

When impacts with an EES over or under 56 kph were compared, a greater proportion of impacts above 56 kph involved intrusion of 10cm or greater.

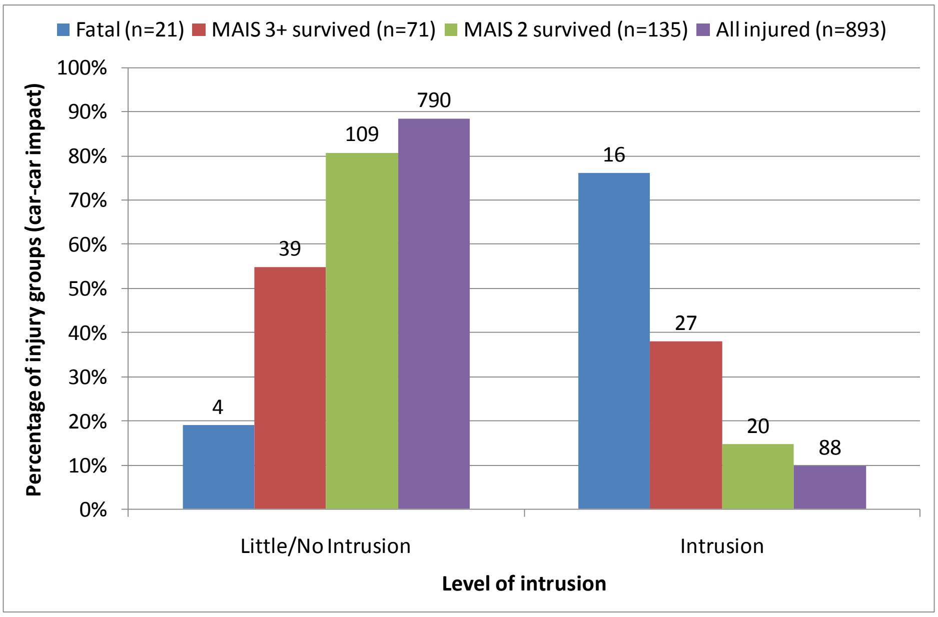


**Figure 5-12. Level of intrusion as a percentage of injury group for drivers in car-car/LGV impacts in GB**

Figure 5-13, Figure 5-14, and Figure 5-15 show the injury distributions for MAIS2 surviving drivers, MAIS3+ surviving drivers and fatally injured drivers. In GB the most frequent injuries are to the thorax, legs, and arms for all injury severities. The injury distribution of drivers is generally similar to the distribution of front seat passengers (shown in Appendix B), although front seat passengers receive fewer leg injuries. The injury distribution of rear seat passengers is substantially different to that of drivers and front seat passengers, although the sample size is relatively small for rear seat passengers. Arm injuries are most frequent for MAIS 2 casualties, and abdomen injuries are most frequent for MAIS 3+ casualties.

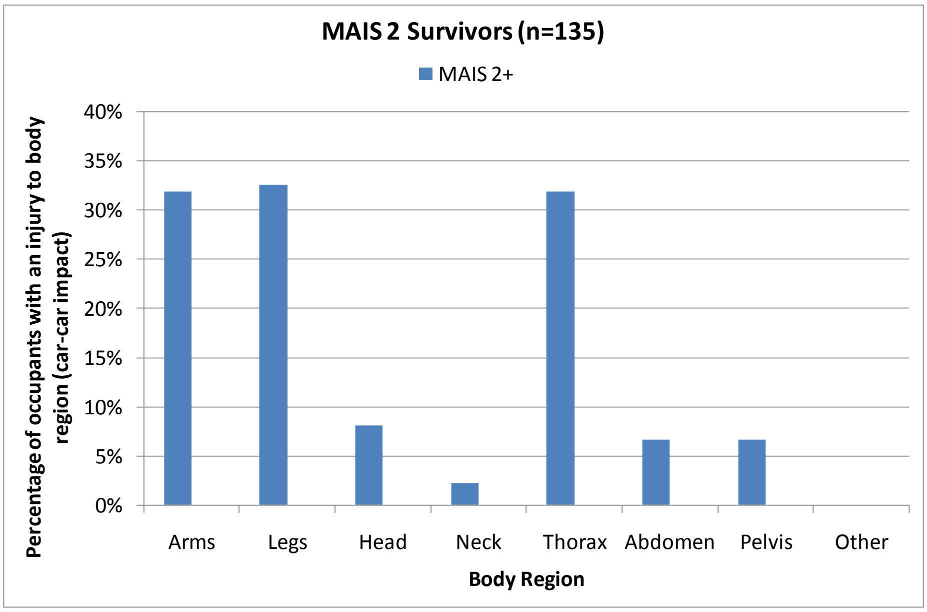


**Figure 5-13. Injury distribution for MAIS2 surviving drivers in car-car/LGV impacts in GB**

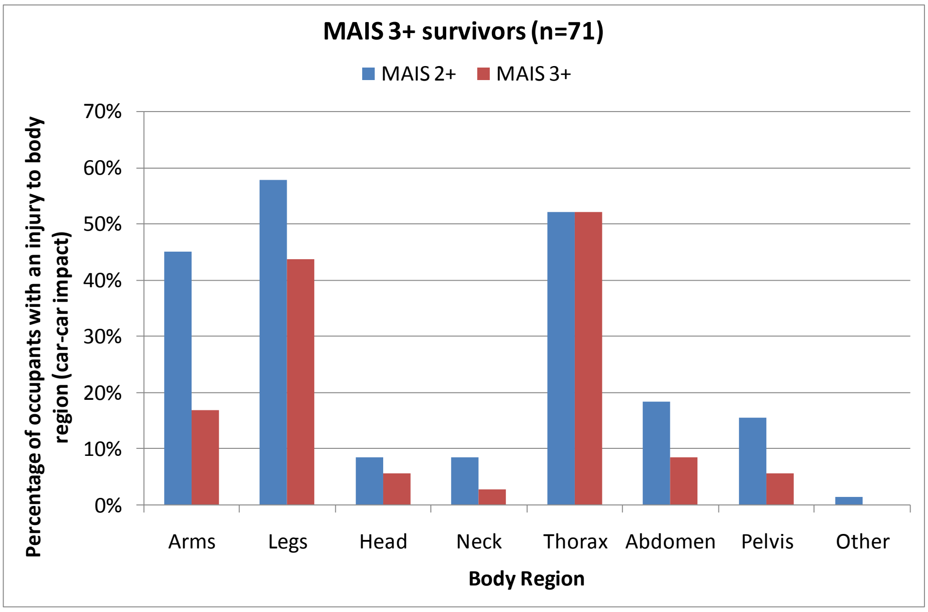


**Figure 5-14. Injury distribution for MAIS3+ surviving drivers in car-car/LGV impacts in GB**

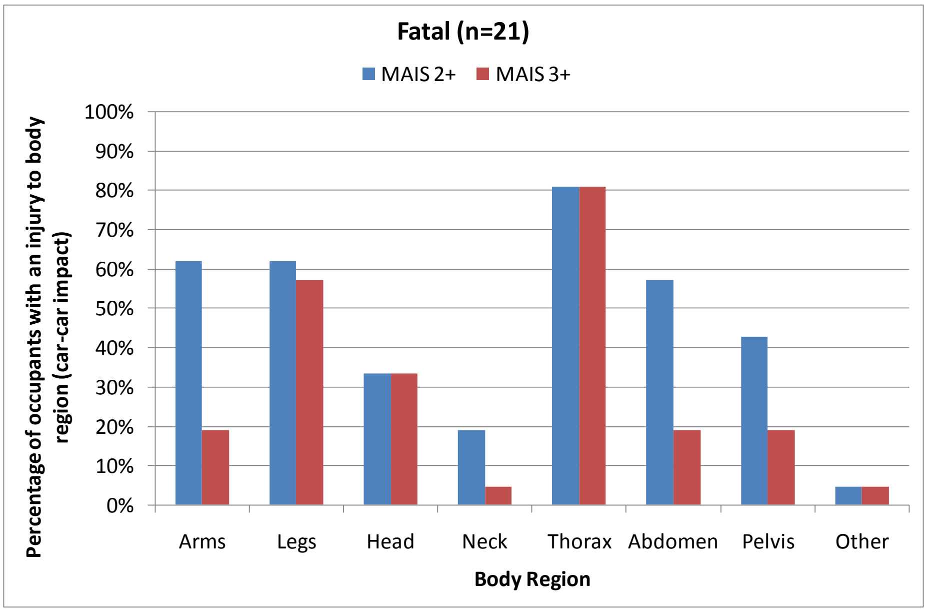


**Figure 5-15. Injury distribution for car driver fatalities in car-car/LGV impacts in GB**

Figure 5-16, Figure 5-17, and Figure 5-18 show the injury mechanism for different body regions for MAIS 2 surviving, MAIS 3+ surviving, and fatally injured drivers respectively. In CCIS, each injury is associated with a cause. These different causes were combined into four groups for this analysis: injuries induced by the restraint system, including the seat belt and airbags; injuries induced by contact with structures inside the vehicle which were not intruding; injuries induced by contact with structures inside the vehicle which had intruded as a result of the accident; and other causes (which included non-contact injuries and impacts with external objects).

For MAIS2 drivers in GB it was found that injuries are most frequently related to the restraint system, or contact with non-intruding structures. For fatal drivers in GB, injuries are most frequently related to contact with intruding structures. When split by body region, head injuries are most commonly caused by impacts with the intruding structures for fatally injured drivers. Thorax injuries are most commonly related to contact with intruding structures for fatally injured drivers, but related to the restraint systems for MAIS2 and MAIS3+ drivers. Abdomen injuries are also most frequently related to the restraint system, or contact with intruding structures. MAIS2 drivers’ leg and arm injuries are most commonly related to contact with non-intruding structures, whereas intruding structures are the most common cause of leg and arm injuries in fatal drivers.

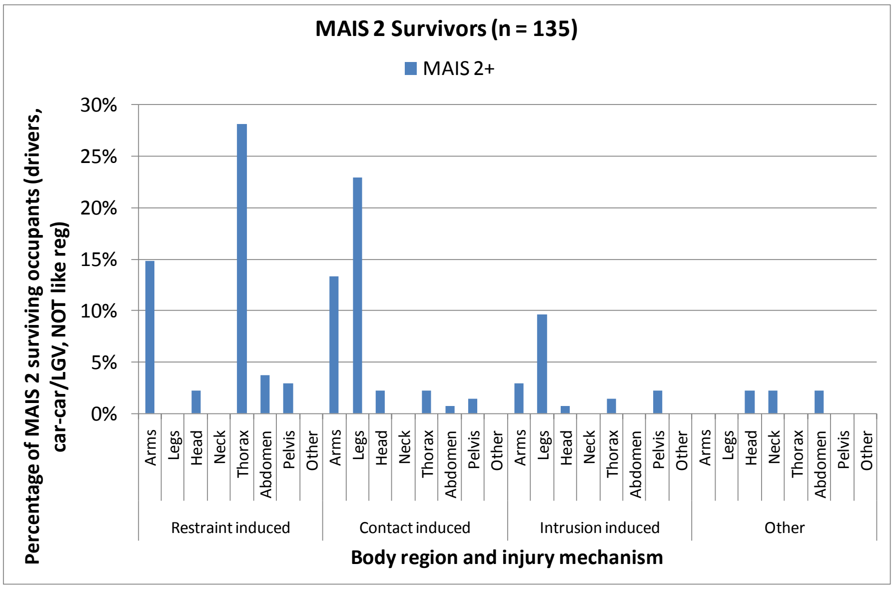


**Figure 5-16. Injury mechanisms for MAIS2 surviving car drivers in impacts with cars/LGVs in GB**

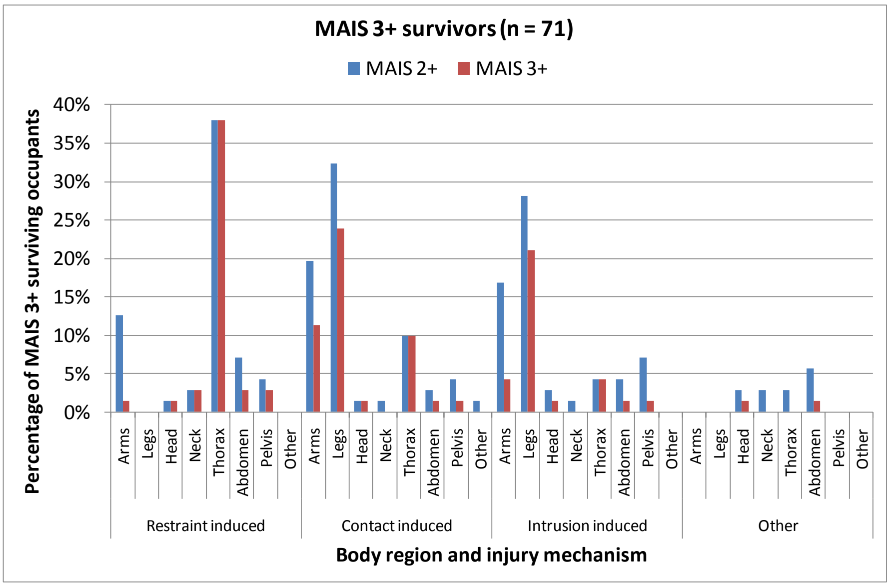


**Figure 5-17. Injury mechanisms for MAIS3+ surviving car drivers in impacts with cars/LGVs in GB**

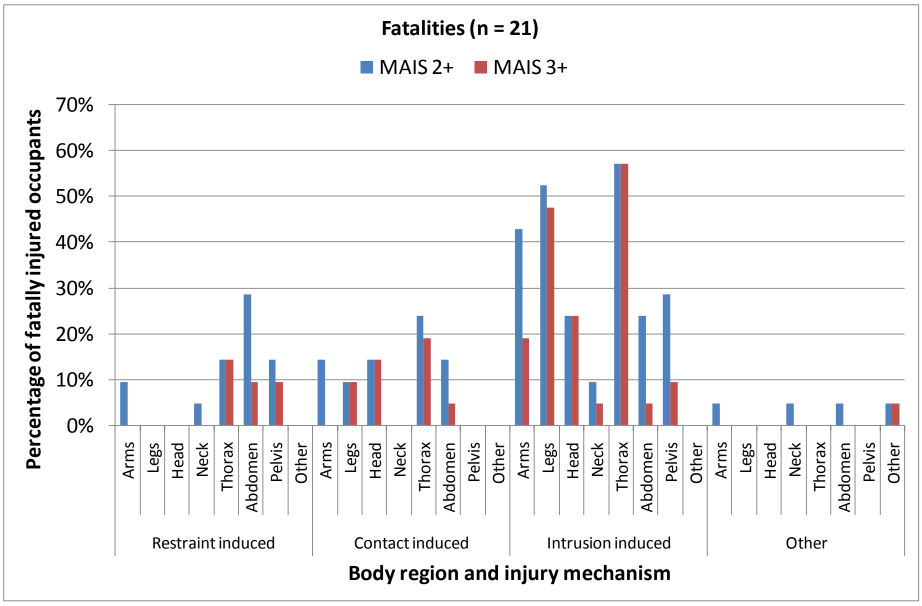


**Figure 5-18. Injury mechanisms for fatally injured car drivers in impacts with cars/LGVs in GB**

Figure 5-19 shows the type of restraint systems that were fitted for the drivers in the sample, looking at whether a pretensioner or load limiter was fitted. The purpose of a pretensioner is to remove slack from the restraint system as soon as the impact occurs, which gives the restraint system the maximum amount of time in which to operate. The purpose of a load limiter is to pay out the seat belt if the belt loads are above a certain threshold. Paying out the seat belt reduces these loads.

The vast majority of the casualties had restraint systems fitted with both a load limiter and pretensioner. Because such a large proportion had both a load limiter and pretensioner, it is not possible to determine whether occupants who did not have one or both of these devices had a higher rate of injury, or whether the rates of injury to different body regions depended on the type of restraint system fitted. This was also the case for front seat passengers (which are shown in Appendix B). The majority of rear seat passengers had a normal belt, with neither a pretensioner nor load limiter.

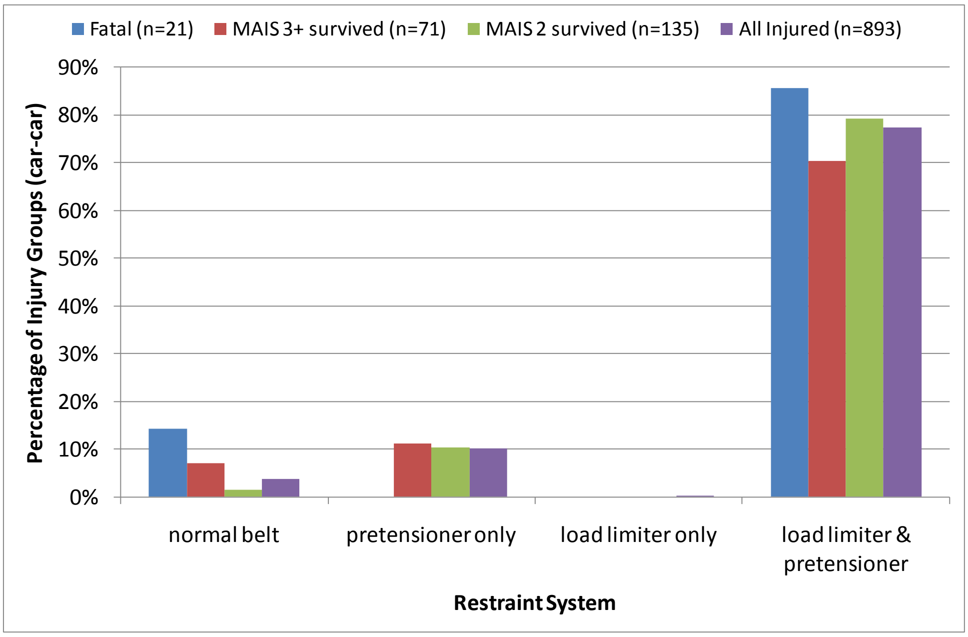


**Figure 5-19. Restraint system fitted for car drivers in car-car/LGV impacts in GB**

Figure 5-20 shows the distribution of age and gender of drivers of cars that impacted cars/LGVs in GB as a percentage of the injury group. Elderly (aged 66+) drivers are over-represented for fatalities, most noticeably for males, however at lower injury levels there is a far smaller proportion of elderly casualties. The age and gender distribution of drivers is different to the distribution for front and rear seat passengers (these distributions can be seen in Appendix B). The majority of front seat passengers are female, and a large proportion of these are elderly. Rear seat passengers are of both genders, but have a higher proportion of children and young adults than in the front seats. This has implications on the type of dummy which should be used in the different seating positions. It should be noted that the CCIS data is not representative of the national data as regards occupant age. There is a greater proportion of the occupants in CCIS who are elderly (aged 66 or older), and a smaller proportion who are aged 12-25 years (see Appendix A). This should be taken into account when interpreting the data presented.

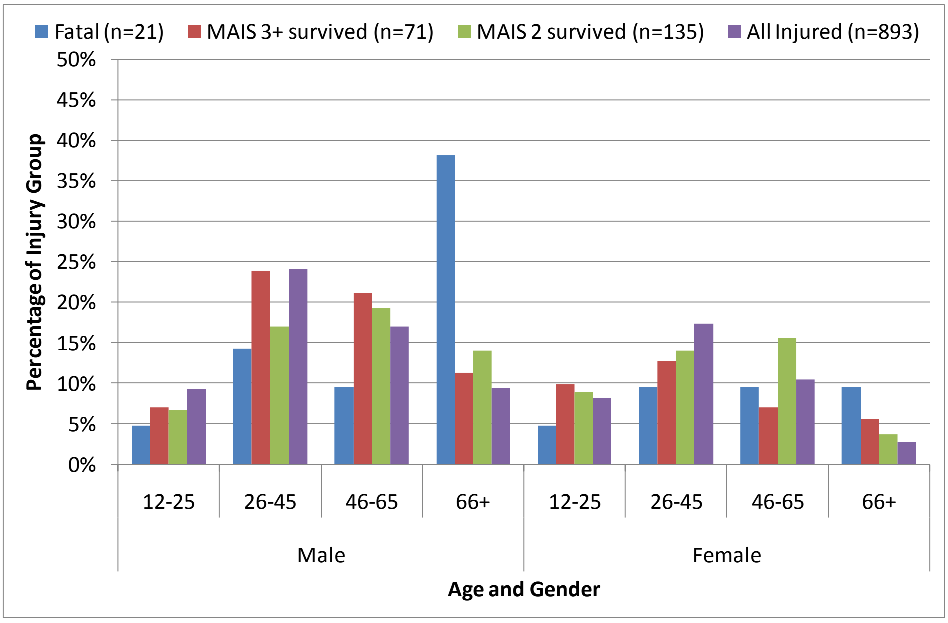


**Figure 5-20. Distribution of age and gender related to injury severity for drivers of cars in impacts with cars/LGVs in GB**

Figure 5-21 and Figure 5-22 explore the relationship between age, gender, and injury. They show the proportion of MAIS 2 surviving drivers receiving AIS 2 injuries to the different body regions, split by gender and age respectively. Figure 5-21 shows that the body regions injured for male and female drivers are similar, and a chi-squared test confirms that there are no statistically significant differences. Unfortunately this analysis could not be performed for front seat passengers because the sample size was not large enough.

Figure 5-22 shows that elderly drivers have a higher rate of thorax injury than younger drivers.

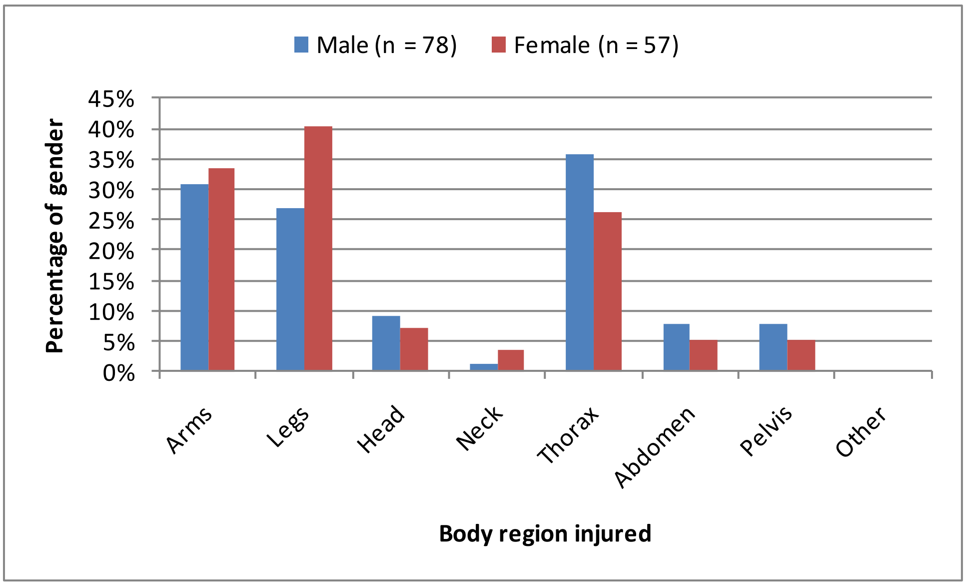


**Figure 5-21. Relationship between gender and body regions injured, for MAIS 2 surviving drivers in car-car/LGV impacts in GB**

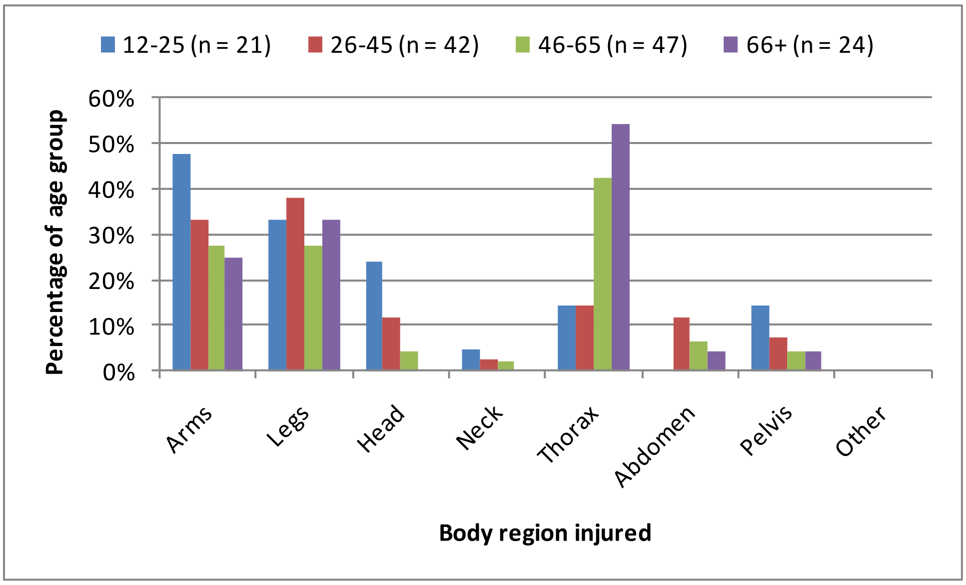


**Figure 5-22. Relationship between age and body regions injured, for MAIS 2 surviving drivers in car-car/LGV impacts in GB**

*5.3.2.2 Drivers and front seat passengers in car-car/LGV impacts in Germany*

The figures in this section show the results for drivers and front seat passengers in car-car/LGV impacts in Germany. These results are compared side-by-side in Appendix C with the figures for drivers in car-car/LGV impacts in Great Britain. It should be noted that there were two fatalities in the German sample, but these are not shown in the following graphs because there were too few fatalities to make any conclusions.

The principle direction of force recorded for drivers and front seat passengers in car-car/LGV impacts in the German in-depth data is shown in Figure 5-23. The largest proportion of impacts have a principle direction of force of 12 o'clock, however there is a higher proportion of oblique impacts in Germany than was seen in the in-depth data from Great Britain.

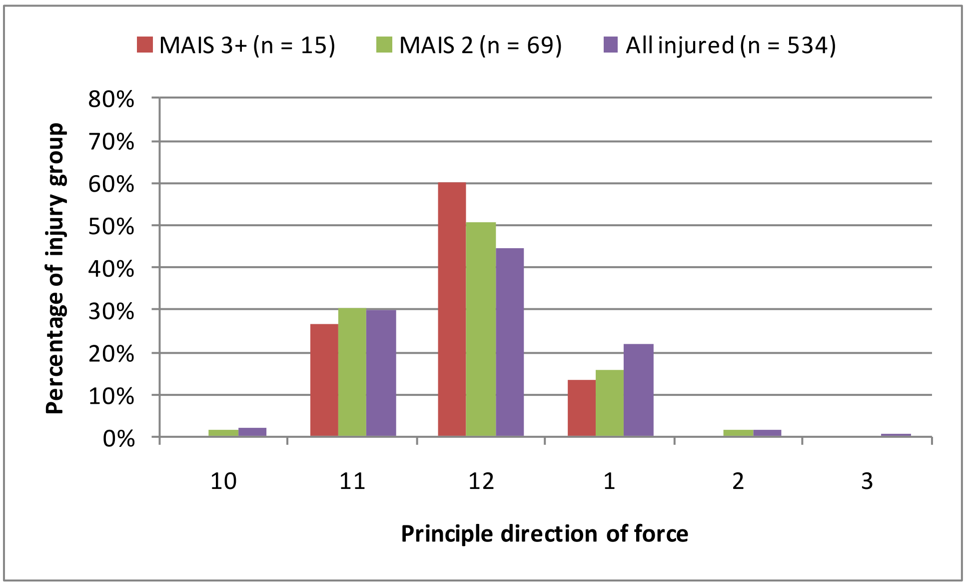


**Figure 5-23. Principle direction of force for car-car/LGV impacts in Germany**

Figure 5-24 shows the vehicle overlap for cars in car to car/LGV impacts in Germany as a percentage of the injury group of the front row occupants of that car. This figure shows that a large proportion of impacts have a large overlap (>90%), as was shown for GB.

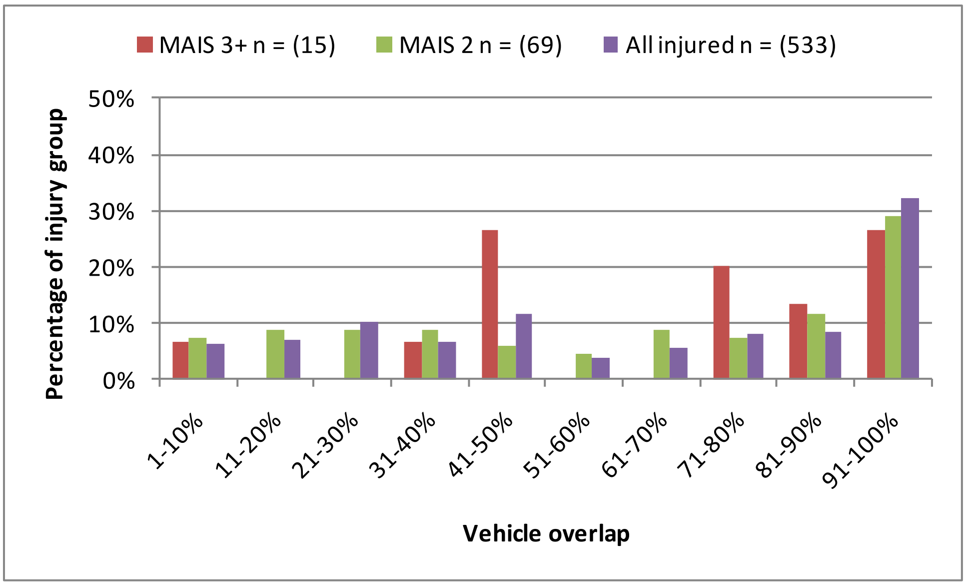


**Figure 5-24. Vehicle overlap as a percentage of injury group in Germany**

Figure 5-25 shows that 96% of MAIS2 front row occupants were at an Equivalent Energy Speed (EES) of 56kph or less, and 95% were at an EES of 50kph or less. These proportions are very similar to the proportions that were seen for Great Britain.

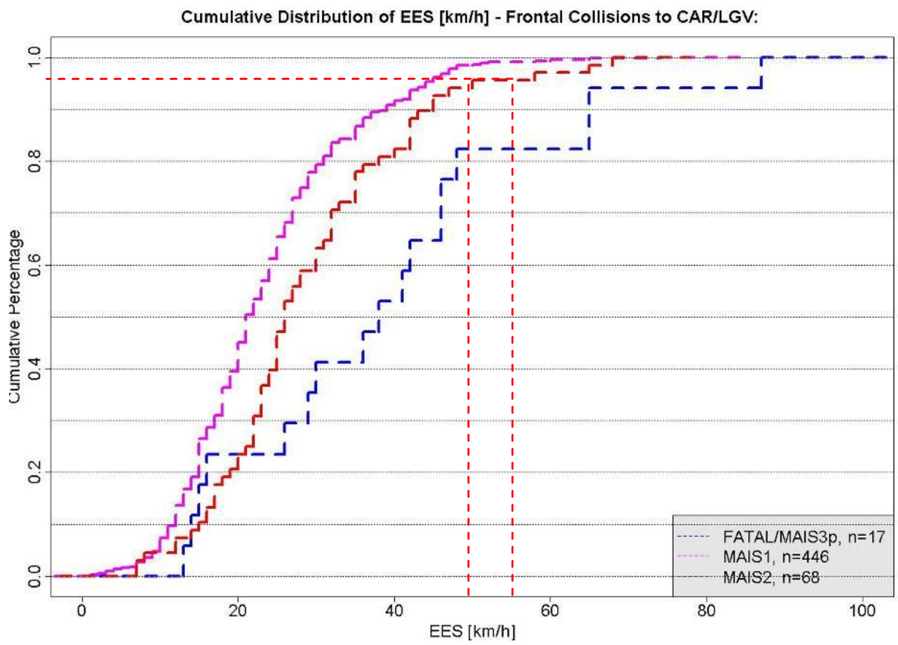


**Figure 5-25. Cumulative percentage of EES for car-car/LGV impacts in Germany**

The proportion of impacts in Germany which were covered by the regulatory test is shown in Figure 5-26. The majority of impacts were not represented by the regulatory test, which was also the case for the in-depth data from Great Britain.

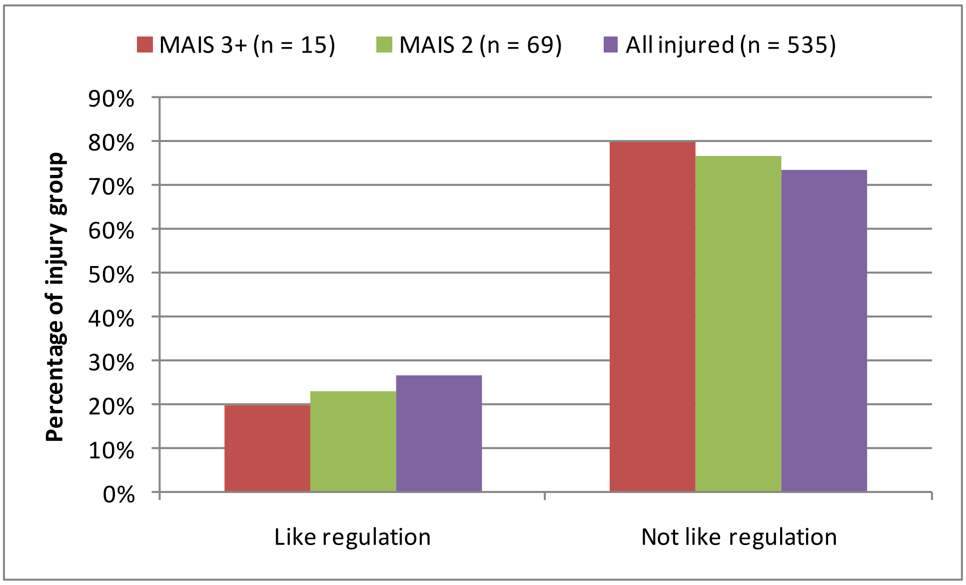


**Figure 5-26. Proportion of impacts covered by the regulatory test for car-car/LGV impacts in Germany**

The proportion of occupants where there was significant intrusion recorded in the German in-depth data is shown in Figure 5-27. Similar to Great Britain, this shows that the proportion of occupants with significant intrusion increases as the injury level increases. However, the proportion of occupants with significant intrusion is much lower in Germany than in Great Britain. This may be because intrusion has been measured differently in the German in-depth data. Intrusion in the German data is defined as a loss of stability in the compartment (of the A-pillar, dashboard, or firewall) where the door space has been reduced by more than 10cm. This is different to the definition used in CCIS, where intrusion was defined as intrusion of 10cm or more of the footwell, A-pillar, facia, or steering wheel. This difference in definition is the most likely reason why less intrusion is seen in the results from Germany.

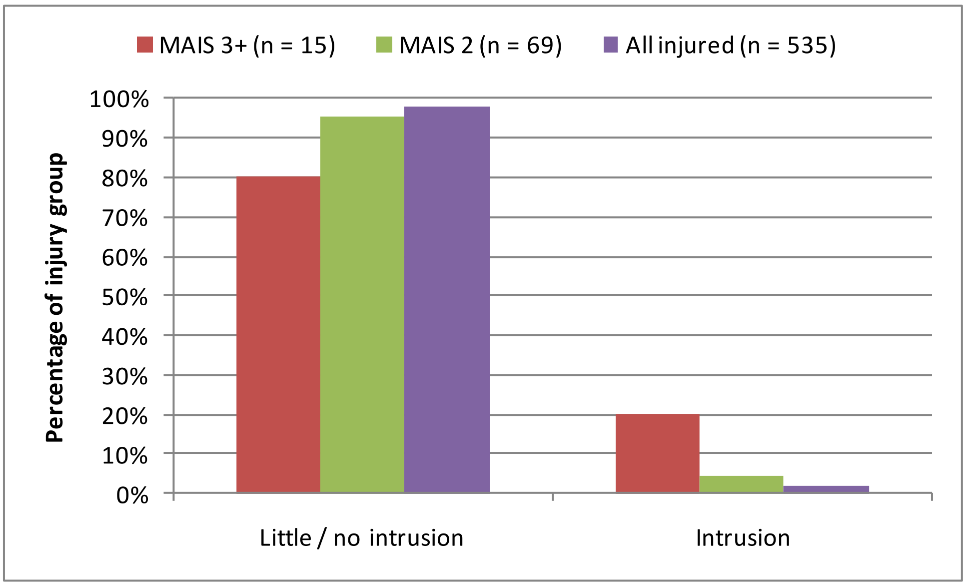


**Figure 5-27. Level of intrusion as a percentage of injury group**

In Germany, the most frequent injuries for MAIS2 occupants were to the thorax followed by the head and arms, as shown in Figure 5-28. The thorax and abdomen were the most frequent injuries for MAIS3+ occupants; however this was a much smaller sample. When compared to the GB data, there is a higher frequency of occupants with head injuries in the German data.

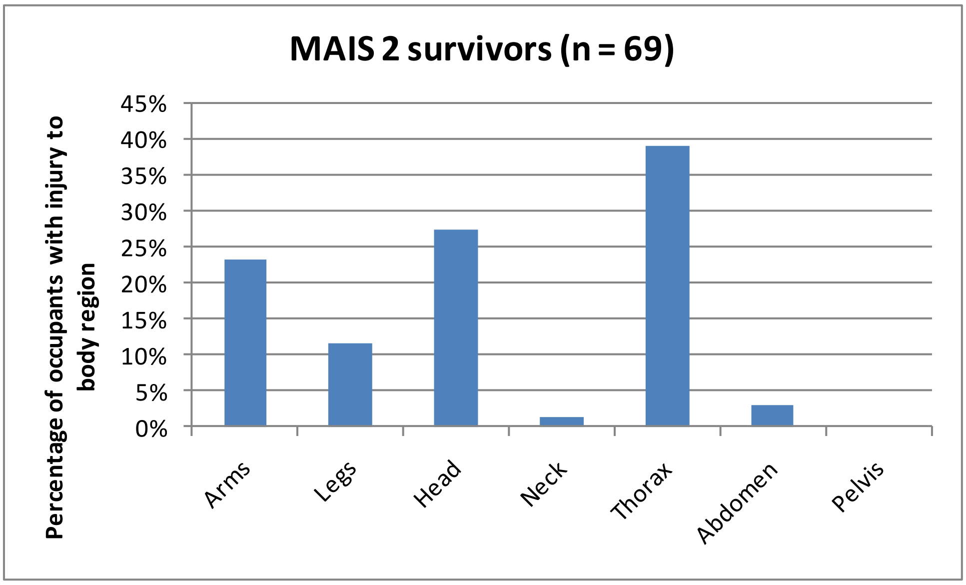


**Figure 5-28. AIS2 injury distribution for MAIS2 survivors**

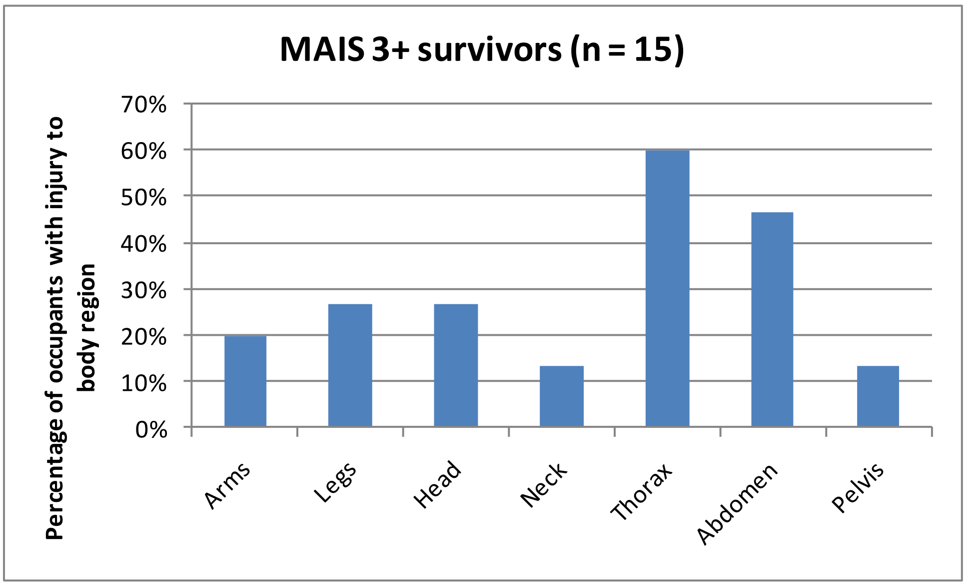


**Figure 5-29. AIS2+ injury distribution for MAIS3+ survivors**

Figure 5-30 shows the distribution of age and gender for the drivers and front seat passengers in impacts with cars/LGVs in the German in-depth data. This is difficult to compare to the data from Great Britain because it combines drivers and front seat passengers. However, it does show that males aged from 26-45 are the most frequently injured casualty group at all injury severities (with the exception of fatalities, but there are only 2 fatalities in the German in-depth data).

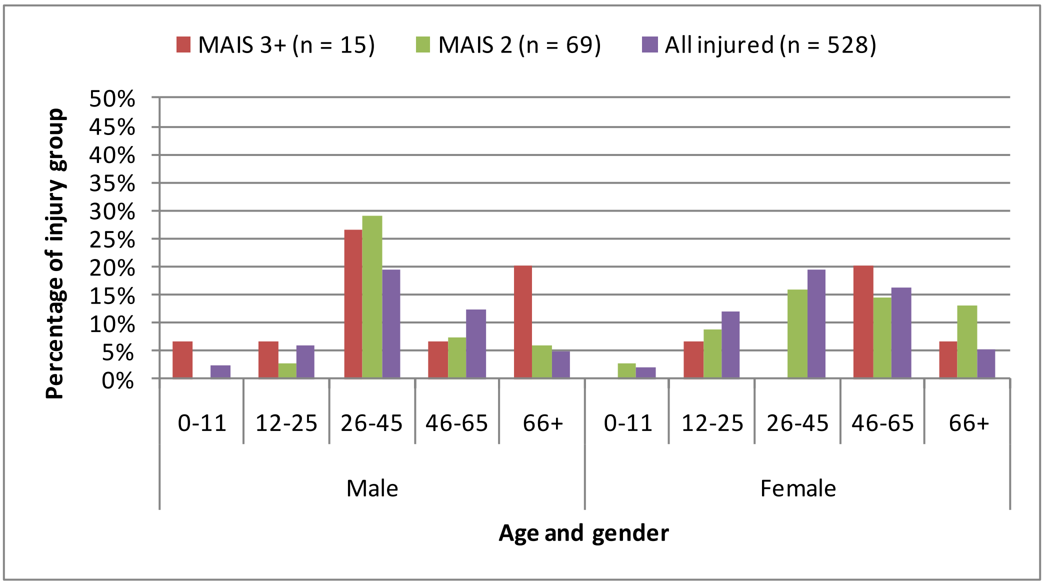


**Figure 5-30. Distribution of age and gender for car-car/LGV impacts in Germany**

### *5.3.3 Summarising results in terms of the target populations for car occupants*

This section uses the breakdown of the target populations in Great Britain and Germany (shown in Figure 5-4 and Figure 5-5 respectively), and the results from the in-depth analysis, to show the proportions of the frontal impact target population which are influenced by different characteristics.

Table 5-2 shows the proportions for car occupants in Great Britain who were fatally injured; Table 5-3 shows the proportions for occupants in Great Britain who received MAIS 3+ injuries and survived; Table 5-4 shows the proportions for occupants in Great Britain who received MAIS 2 injuries and survived; and Table 5-5 shows the proportions for occupants in Germany who received MAIS 2 injuries and survived.

The layout of each table is as follows. The left half of each table gives the proportion of occupants in each subset that had that characteristic. These proportions come from the analysis of the in-depth data, the results of which can be seen in section 5.3.2 and in Appendix B. The right half of the table gives the proportion of all casualties in frontal impacts that had that characteristic. These are calculated by taking the results from the in-depth data, and multiplying them by the percentage of all frontal impact casualties which are included in that subset (shown in Figure 5-4 for Great Britain and Figure 5-5 for Germany).

The values shown in green are those which could be calculated directly from the in-depth accident data. The values in red are those which were estimated, because the sample size in the in-depth data was not large enough to be able to calculate them without large errors. They were estimated using the assumption that the proportions would be the same as for car drivers in impacts with cars/LGVs, which was the largest group.

It should be noted that these estimates will lead to errors in the proportion of casualties with each characteristic in the target population. These errors will be larger where more estimations are made. This problem is greatest for fatalities, because this was the smallest sample.

These tables can be used to estimate the proportion of casualties which could be affected by a regulatory change. For example, Table 5-2 shows that fatalities in impacts where both longitudinals were loaded include 18% of the fatalities in the target population, compared to fatalities in impacts with no longitudinal loading which make up 5% of the target population. This could be used to help estimate the affect of introducing a full with test compared to a low overlap test. These tables could also be used to help estimate, for example, the possible magnitude of the affect of the introduction of measures to address thorax injury.

**Table 5-2. Car occupant fatalities in Great Britain – summary of target population sizes**

| | Characteristic | Proportion of subset | | | | | | Proportion of target population | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Car-car/LGV | | Car-HGV/bus | Car-wide | Car-narrow | Car-all | Car-car/LGV | | Car-HGV/bus | Car-wide | Car-narrow | Car-all | All |
| | | DRV | FSP | DRV+FSP | DRV+FSP | DRV+FSP | RSP | DRV | FSP | DRV+FSP | DRV+FSP | DRV+FSP | RSP | All |
| | | n=21 | n=8 | n=12 | n=6 | n=1 | n=1 | - | - | - | - | - | - | - |
| Impact configuration | PDOF = 12 | 67% | 67% | 67% | 67% | 67% | 67% | 15% | 5% | 7% | 4% | 3% | 1% | 35% |
| | No long. loading | 10% | 10% | 10% | 10% | 10% | 10% | 2% | 1% | 1% | 1% | 1% | 0% | 5% |
| | 1 long. loaded | 57% | 57% | 57% | 57% | 57% | 57% | 13% | 4% | 6% | 3% | 3% | 1% | 30% |
| | 2 long. loaded | 34% | 34% | 34% | 34% | 34% | 34% | 8% | 2% | 3% | 2% | 2% | 0% | 18% |
| | >90% overlap | 28% | 28% | 28% | 28% | 28% | 28% | 6% | 2% | 3% | 2% | 1% | 0% | 15% |
| | EES <= 50 kph | 39% | 39% | 39% | 39% | 39% | 39% | 9% | 3% | 4% | 2% | 2% | 0% | 20% |
| | EES <= 56 kph | 46% | 46% | 46% | 46% | 46% | 46% | 11% | 3% | 5% | 3% | 2% | 0% | 24% |
| | Represented by R94 test | 20% | 20% | N/A | 20% | N/A | N/A | 5% | 1% | N/A | 1% | N/A | N/A | 7% |
| Casualties and their injuries | Gender: female | 33% | 33% | 33% | 33% | 33% | 33% | 8% | 2% | 3% | 2% | 2% | 0% | 17% |
| | Age: elderly (66+) | 48% | 48% | 48% | 48% | 48% | 48% | 11% | 3% | 5% | 3% | 2% | 0% | 25% |
| | Head AIS 2+ | 33% | 33% | 33% | 33% | 33% | 33% | 8% | 2% | 3% | 2% | 2% | 0% | 17% |
| | Thorax AIS 2+ | 80% | 80% | 80% | 80% | 80% | 80% | 18% | 6% | 8% | 5% | 4% | 1% | 42% |
| | Leg AIS 2+ | 61% | 61% | 61% | 61% | 61% | 61% | 14% | 4% | 6% | 4% | 3% | 1% | 32% |
| | Arm AIS 2+ | 61% | 61% | 61% | 61% | 61% | 61% | 14% | 4% | 6% | 4% | 3% | 1% | 32% |
| | Abdomen AIS 2+ | 58% | 58% | 58% | 58% | 58% | 58% | 13% | 4% | 6% | 3% | 3% | 1% | 30% |
| | Intrusion | 76% | 76% | 76% | 76% | 76% | N/A | 17% | 5% | 8% | 5% | 4% | N/A | 39% |
| | All | 100% | 100% | 100% | 100% | 100% | 100% | 23% | 7% | 10% | 6% | 5% | 1% | 52% |

**Table 5-3. MAIS 3+ surviving car occupant casualties in Great Britain – summary of target population sizes**

| | Population | Proportion of subset | | | | | | Proportion of target population | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Car-car/LGV | | Car-HGV/bus | Car-wide | Car-narrow | Car-all | Car-car/LGV | | Car-HGV/bus | Car-wide | Car-narrow | Car-all | All |
| | | DRV | FSP | DRV+FSP | DRV+FSP | DRV+FSP | RSP | DRV | FSP | DRV+FSP | DRV+FSP | DRV+FSP | RSP | All |
| | | n=71 | n=26 | n=16 | n=13 | n=4 | n=16 | - | - | - | - | - | - | - |
| Impact configuration | PDOF = 12 | 69% | 88% | 69% | 69% | 69% | 69% | 19% | 8% | 3% | 5% | 4% | 4% | 43% |
| | No long. loading | 10% | 4% | 10% | 10% | 10% | 10% | 3% | 0% | 0% | 1% | 1% | 2% | 7% |
| | 1 long. loaded | 52% | 43% | 52% | 52% | 52% | 52% | 15% | 4% | 2% | 4% | 3% | 3% | 30% |
| | 2 long. loaded | 38% | 54% | 38% | 38% | 38% | 38% | 11% | 5% | 2% | 3% | 2% | 2% | 24% |
| | >90% overlap | 36% | 46% | 36% | 36% | 36% | 36% | 10% | 4% | 1% | 3% | 2% | 2% | 23% |
| | EES <= 50 kph | 83% | 86% | 83% | 83% | 83% | 83% | 23% | 8% | 3% | 6% | 5% | 5% | 49% |
| | EES <= 56 kph | 90% | 90% | 90% | 90% | 90% | 90% | 25% | 8% | 4% | 6% | 5% | 5% | 54% |
| | Represented by R94 test | 34% | 23% | N/A | 34% | N/A | N/A | 10% | 2% | N/A | 2% | N/A | N/A | 14% |
| Casualties and their injuries | Gender: female | 34% | 80% | 34% | 34% | 34% | 34% | 10% | 7% | 1% | 2% | 2% | 2% | 25% |
| | Age: elderly (66+) | 16% | 42% | 16% | 16% | 16% | 16% | 4% | 4% | 1% | 1% | 1% | 1% | 12% |
| | Head AIS 2+ | 8% | 12% | 8% | 8% | 8% | 8% | 2% | 1% | 0% | 1% | 0% | 0% | 5% |
| | Thorax AIS 2+ | 52% | 46% | 52% | 52% | 52% | 52% | 15% | 4% | 2% | 4% | 3% | 3% | 31% |
| | Leg AIS 2+ | 58% | 23% | 58% | 58% | 58% | 58% | 16% | 2% | 2% | 4% | 3% | 3% | 32% |
| | Arm AIS 2+ | 45% | 62% | 45% | 45% | 45% | 45% | 13% | 6% | 2% | 3% | 3% | 3% | 29% |
| | Abdomen AIS 2+ | 19% | 35% | 19% | 19% | 19% | 19% | 5% | 3% | 1% | 1% | 1% | 1% | 13% |
| | Intrusion | 38% | 20% | 38% | 38% | 38% | N/A | 11% | 2% | 2% | 3% | 2% | N/A | 19% |
| | All | 100% | 100% | 100% | 100% | 100% | 100% | 28% | 9% | 4% | 7% | 6% | 6% | 61% |

**Table 5-4. MAIS 2 surviving car occupant casualties in Great Britain – summary of target population sizes**

| | Population | Proportion of subset | | | | | | Proportion of target population | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Car-car/LGV | | Car-HGV/bus | Car-wide | Car-narrow | Car-all | Car-car/LGV | | Car-HGV/bus | Car-wide | Car-narrow | Car-all | All |
| | | DRV | FSP | DRV+FSP | DRV+FSP | DRV+FSP | RSP | DRV | FSP | DRV+FSP | DRV+FSP | DRV+FSP | RSP | All |
| | | n=135 | n=49 | n=24 | n=32 | n=13 | n=22 | - | - | - | - | - | - | - |
| Impact configuration | PDOF = 12 | 66% | 65% | 79% | 75% | 66% | 68% | 22% | 7% | 3% | 9% | 4% | 5% | 50% |
| | No long. loading | 10% | 8% | 33% | 19% | 10% | 13% | 3% | 1% | 1% | 2% | 1% | 4% | 12% |
| | 1 long. loaded | 50% | 59% | 50% | 35% | 50% | 36% | 17% | 6% | 2% | 4% | 3% | 3% | 35% |
| | 2 long. loaded | 39% | 33% | 17% | 44% | 39% | 50% | 13% | 4% | 1% | 5% | 2% | 4% | 29% |
| | >90% overlap | 35% | 31% | 29% | 38% | 35% | 50% | 12% | 3% | 1% | 5% | 2% | 4% | 27% |
| | EES <= 50 kph | 90% | 97% | 90% | 94% | 90% | 90% | 31% | 11% | 4% | 11% | 5% | 6% | 67% |
| | EES <= 56 kph | 95% | 100% | 95% | 96% | 95% | 94% | 32% | 11% | 4% | 12% | 6% | 7% | 70% |
| | Represented by R94 test | 33% | 29% | N/A | 27% | N/A | N/A | 11% | 3% | N/A | 3% | N/A | N/A | 18% |
| Casualties and their injuries | Gender: female | 41% | 85% | 25% | 35% | 41% | 54% | 14% | 9% | 1% | 4% | 2% | 4% | 35% |
| | Age: elderly (66+) | 17% | 28% | 8% | 34% | 17% | 9% | 6% | 3% | 0% | 4% | 1% | 1% | 15% |
| | Head AIS 2+ | 8% | 2% | 25% | 10% | 8% | 4% | 3% | 0% | 1% | 1% | 0% | 0% | 6% |
| | Thorax AIS 2+ | 32% | 39% | 16% | 25% | 32% | 28% | 11% | 4% | 1% | 3% | 2% | 2% | 23% |
| | Leg AIS 2+ | 33% | 12% | 13% | 15% | 33% | 4% | 11% | 1% | 1% | 2% | 2% | 0% | 17% |
| | Arm AIS 2+ | 32% | 31% | 42% | 31% | 32% | 54% | 11% | 3% | 2% | 4% | 2% | 4% | 25% |
| | Abdomen AIS 2+ | 7% | 16% | 5% | 19% | 7% | 19% | 2% | 2% | 0% | 2% | 0% | 1% | 8% |
| | Intrusion | 15% | 4% | 17% | 13% | 15% | N/A | 5% | 0% | 1% | 2% | 1% | N/A | 9% |
| | All | 100% | 100% | 100% | 100% | 100% | 100% | 34% | 11% | 4% | 12% | 6% | 7% | 74% |

**Table 5-5. MAIS 2 surviving car occupant casualties in Germany – summary of target population sizes**

| | Population | Proportion of subset | | Proportion of target population | |
|---|---|---|---|---|---|
| | | Car-car/LGV | All | Car-car/LGV | All |
| | | DRV+FSP | All | DRV+FSP | All |
| | | n=69 | - | - | - |
| Impact configuration | PDOF = 12 | 51% | 51% | 25% | 40% |
| | No long. loading | - | - | - | - |
| | 1 long. loaded | - | - | - | - |
| | 2 long. loaded | - | - | - | - |
| | >90% overlap | 29% | 29% | 14% | 23% |
| | EES <= 50 kph | 95% | 95% | 47% | 74% |
| | EES <= 56 kph | 96% | 96% | 47% | 75% |
| | Represented by R94 test | 27% | 20%* | 13% | 16%* |
| Casualties and their injuries | Gender: female | 55% | 55% | 27% | 43% |
| | Age: elderly (66+) | 19% | 19% | 9% | 15% |
| | Head AIS 2+ | 27% | 27% | 13% | 21% |
| | Thorax AIS 2+ | 39% | 39% | 19% | 30% |
| | Leg AIS 2+ | 11% | 11% | 5% | 9% |
| | Arm AIS 2+ | 23% | 23% | 11% | 18% |
| | Abdomen AIS 2+ | 3% | 3% | 1% | 2% |
| | Intrusion | 4% | 4% | 2% | 3% |
| | All | 100% | 100% | 49% | 78% |

*calculated by assuming that only impacts with cars/LGVs and wide objects would be represented by R94 test

### *5.3.4 $N_1$ vehicles*

The sample from the HVCIS fatals database included 128 occupants of $N_1$ vehicles who were fatally injured in a frontal impact. The seating position of these occupants is shown in Figure 5-31. Approximately 78% of the $N_1$ occupant fatalities were drivers, which is similar to the 75% of car occupant fatalities who were drivers.

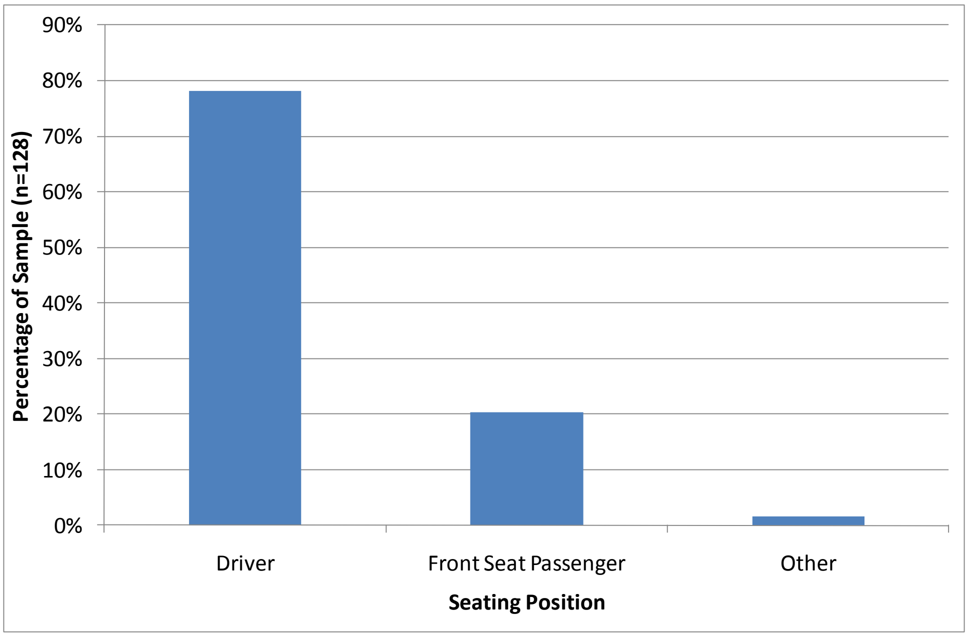


**Figure 5-31. Seating position of occupant fatalities in $N_1$ vehicles**

Figure 5-32 shows the seat belt use of the fatally injured occupants in $N_1$ vehicles. This figure includes the occupants where it was not known whether they were wearing a seat belt. For occupants with a known seat belt use the estimated proportion of occupants who were wearing a seatbelt is 35%. This is much lower than the seat belt wearing rate for fatalities in cars, which was approximately 70% for car driver fatalities.

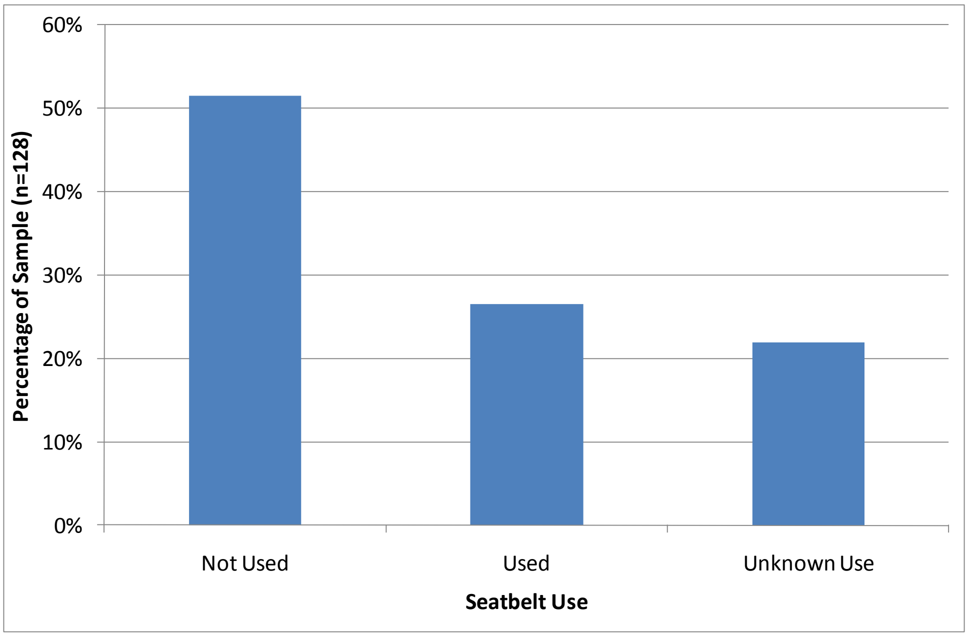


**Figure 5-32. Seat belt use of occupant fatalities in $N_1$ vehicles**

The age and gender of the $N_1$ vehicle fatalities are shown in Figure 5-33 and Figure 5-34 respectively. These show some differences to the distribution that was seen for car occupant fatalities. To begin with, the vast majority of $N_1$ vehicle fatalities are male, about 95%. There are also very few elderly fatalities, in contrast to car occupants where this was one of the largest groups.

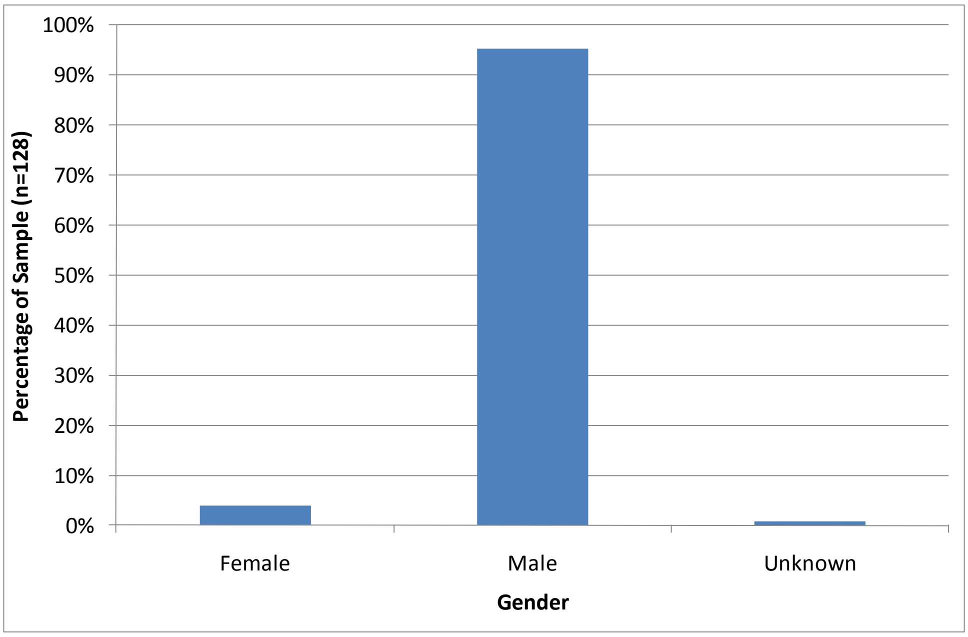


**Figure 5-33. Gender of occupant fatalities in $N_1$ vehicles**

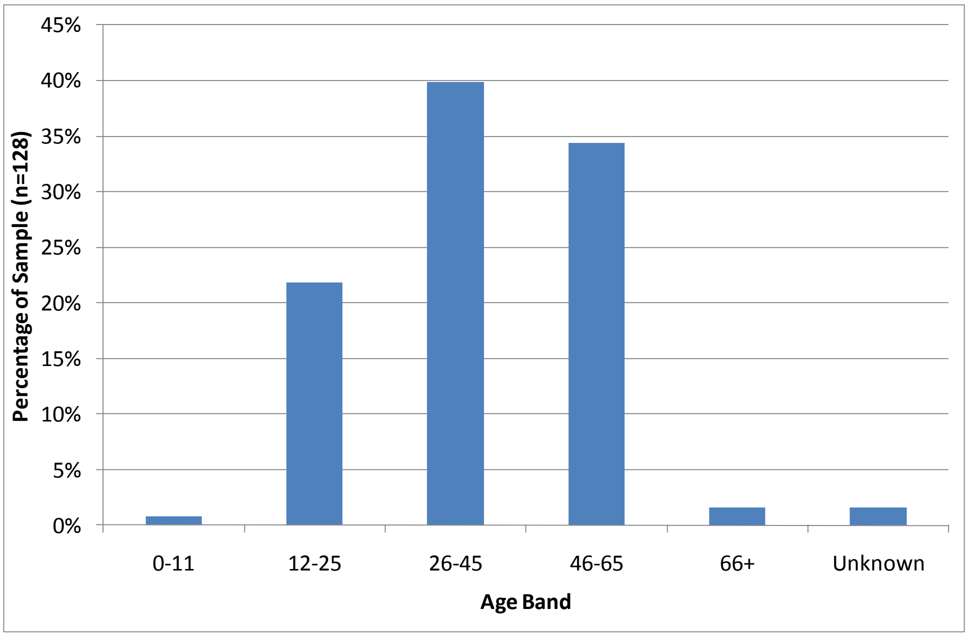


**Figure 5-34. Age of occupant fatalities in $N_1$ vehicles**

## 5.4 Summary of findings and regulatory implications

### *5.4.1 Identification of target population*

The target population is defined as those casualties who are likely to experience some benefit from the countermeasure being considered, i.e. potential changes to Regulation 94.

One of the most important findings from this study was the large effect on the size of the target populations of excluding casualties who would not likely benefit from potential changes to improve Regulation 94, namely those who were unbelted, were seated in front of an unbelted occupant or were involved in an accident in which the vehicle rolled over. Once these occupants were excluded, the size of the target populations as a percentage of all car occupant casualties in frontal impacts were as follows:

- Fatalities – 52% in Great Britain, 64% in Germany, 80% in France
- MAIS 3+ survived – 61% in Great Britain, 78% in Germany
- MAIS 2 survived – 74% in Great Britain, 78% in Germany

The percentage of casualties in the target population for Great Britain is smaller than in France and Germany. The percentage of occupants in the target population in France is larger than in the other two countries. This may be because for France, national data rather than detailed accident data was used to determine seatbelt use and it is likely that seat belt use is over-estimated in this database.

The regulatory implication is that measures to improve protection offered for those casualties excluded from the target population, in particular to increase seatbelt wearing rates, should be considered strongly because they could offer substantial benefit on their own merits and maximise the benefit of other potential changes to Regulation 94.

It should be noted that all the percentages quoted in this summary are of the total number of car occupant casualties in frontal impacts.

### 5.4.2 Impact configuration

The approximate sizes of the target populations in the different impact categories are shown in Table 5-6. This shows that:

- Impacts with cars or LGVs are generally the largest target population group in all three countries and at all injury levels. This indicates that car-to-car / car-to-LGV compatibility should be an important consideration for potential changes to Regulation 94.
    - There are differences between the three countries. For example, for fatalities and MAIS 3+ surviving casualties, the proportion of HGV/bus, wide and narrow object impacts are greater in France and Germany than in Great Britain. This is partially because the national data in Great Britain contains a greater proportion of car-to-car / LGV impacts.
- The size of the target population group for narrow objects is small; 5-6% of casualties, depending on severity for GB and 10-16% of casualties for Germany. This gives an indication that the benefit of the introduction of a frontal pole test into Regulation 94 would likely be low and hence should not be considered as a high priority.

**Table 5-6. Proportion of all frontal impact casualties in target population groups for different impact configurations**

| Impact with | Fatal | | | MAIS 3+ survived | | MAIS 2 survived | |
|---|---|---|---|---|---|---|---|
| | GB | Germany | France | GB | Germany | GB | Germany |
| Car/LGV | 30% | 22% | 26% | 37% | 33% | 45% | 49% |
| HGV/bus | 10% | 11% | 18% | 4% | 13% | 4% | 9% |
| Wide object | 6% | 18% | 36% | 7% | 16% | 12% | 11% |
| Narrow object | 5% | 13% | | 6% | 16% | 6% | 10% |

The characteristics of the impact, such as longitudinal loading and impact severity, were investigated using the in-depth data from Great Britain and Germany. The results of this analysis were as follows:

- Impacts involving direct loading to only one longitudinal (like the current offset test) account for a larger proportion of impacts than other impact types, the next most frequent being impacts directly loading both longitudinals, followed by low overlap impacts with no direct loading to the longitudinals. The target population of impacts loading both longitudinals is 18-29% of all frontal impact casualties, depending on severity. High overlap crashes (> 90% overlap) are a similar proportion, 15-27% of frontal impact casualties in Great Britain and Germany. These are the potential sizes of the populations which could benefit if a full width test was introduced. For Great Britain the target population for low overlap crashes with no direct loading to the longitudinals is 5-12% depending on severity. This indicates that the introduction of a full width overlap test into Regulation 94 should be an important consideration for potential changes to Regulation 94.
- There is a large proportion of impacts with no direct loading of the longitudinals in impacts with HGVs or buses due to underride. However, because impacts with these vehicles are a small group, the target population of these impacts is approximately 1% of casualties.

- Increasing the Equivalent Energy Speed (EES) from 50 kph to 56 kph (which approximately relate to the severity of Regulation and EuroNCAP tests respectively) increases the target population by 3-5% of all frontal impact casualties in Great Britain depending on severity, although this increase is smaller in Germany (about 1%). However, it should be noted that over half of fatalities are in impacts with a higher severity than both these speeds. There are also a large proportion of fatalities at relatively low speeds, the majority of which are elderly occupants. This indicates that the potential benefit to Regulation 94 to increase the test severity to that of the Euro NCAP test may not be that high.
- The target population for impacts with a principle direction of force of 12 o'clock is smaller in Germany than in Great Britain. In Germany the target population of casualties in oblique frontal impacts is approximately 40% for MAIS 2 surviving casualties, compared to 24% in Great Britain.
- The target population of casualties in impacts currently covered by Regulation 94 varies from 7% for fatalities to 18% for MAIS 2 surviving casualties (16% in Germany). This means that the potential benefit of increasing the scope of the target population could be large, by increasing the proportion of impacts that are covered by the regulation.
- The in-depth data from Great Britain suggests a strong relationship between intrusion into the passenger compartment and fatal injury. This can be seen in the size of the target population where there was intrusion, which is 39% of fatalities but only 9% of MAIS 2 surviving casualties. The injury mechanisms for fatalities are also most frequently contact with intruding structures.
- A lower proportion of front seat passengers have significant intrusion into the passenger compartment, because the impact is most often on the driver's side.

### 5.4.3 Population injured

- Drivers are a much larger proportion of the target population than front seat passengers. In car-car/LGV impacts alone in Great Britain, the target population of driver casualties is 23-34% of all frontal impact casualties depending on severity, compared to 7-11% for front seat passengers. The proportion of rear seat passengers in the target population is much smaller than both, partially because of the low seat belt wearing rates in the rear.
- The age and gender of occupants in different seating positions is substantially different. The majority of front seat passengers are female, and a large proportion of these are elderly. Female front seat passengers in car-car/LGV impacts account for 7-9% of frontal impact casualties. A large proportion of rear seat passengers are children or young adults. A suitable dummy to represent the most frequently injured casualty in the front passenger seat would therefore represent a female or elderly female, while a suitable dummy in the rear would represent a child or young adult.
- A large proportion of the target population were elderly occupants aged 66 or older, accounting for 12-25% of all frontal impact casualties in Great Britain depending on severity. Even though elderly occupants are over-represented in this CCIS sample, the German analysis also showed that elderly occupants could make up 15% of the target population of MAIS 2 surviving occupants – the same proportion as for MAIS 2 surviving occupants in Great Britain.

### 5.4.4 Frequency and severity of injury

- In Great Britain, for all injury severities, injuries to the thorax, arms, and legs are the most frequent. For fatalities, injuries to the abdomen are also frequent. The target population of casualties with MAIS 2+ injuries to the thorax is 23-42% of casualties depending on severity; arms are 25-32% of casualties; legs are 17-32% of casualties; and abdomen are 30% of fatalities. The dummy used in any regulatory test should be capable of measuring injury criteria in all of these regions, and better protection should be provided for these body regions.

    - The injury distribution in Germany is slightly different - for MAIS 2 surviving occupants more head injuries and fewer leg injuries are seen compared to Great Britain. The target population of MAIS 2 casualties with head injuries in Germany is 21%, compared to 6% in Great Britain, suggesting that measurement of head injury is also important.
    - For Great Britain, for MAIS 2 injured casualties the frequency of AIS 2 thorax injury is substantially higher for older casualties (46 and over) compared to younger casualties (45 and under).

- Impacts with HGVs or buses result in a higher proportion of occupants with head injury compared to impacts with cars or LGVs. Impacts with wide objects result in a lower proportion of occupants with leg injuries, and a higher proportion of occupants with abdominal injuries.
- For car drivers in car-car/LGV impacts in the GB data, the injury mechanisms are related to both the injury severity and the individual body regions.
    - For MAIS 2 surviving drivers, injuries to the thorax are generally related to the restraint system, injuries to the legs are related to contact with non-intruding structures, and injuries to the arms are related to a combination of both these causes (the restraint induced injuries are probably to the clavicle and shoulder area, and the contact injuries are likely to be to other regions of the arms).
    - As the injury severity becomes more severe, a larger proportion of injuries are related to contact with intruding structures. For fatalities, the majority of injuries to all body regions (with the exception of the abdomen) are related to contact with intruding structures. For MAIS 3+ surviving occupants, the majority of thorax injuries are still related to the restraint system, but injuries to the legs are distributed between contact with intruding and non-intruding structures.
- No difference was found in the injury distribution of male and female drivers in impacts with cars or LGVs in Great Britain. The injury distribution of different age drivers showed that the proportion of MAIS 2 casualties receiving thorax injuries is greatest for elderly casualties.

### *5.4.5 Rear seat passengers*

Partially because of their low seat belt use, the number of rear seat passenger casualties in the target population is relatively small – 1% of fatal casualties, 6% of MAIS 3+ surviving casualties, and 7% of MAIS 2 surviving casualties. However, their characteristics are different to those of drivers and front seat passengers.

- A large proportion of rear seat passengers are children or young adults of both genders.
- A large proportion of MAIS 3+ surviving rear seat passengers have AIS 2+ abdomen injuries, although the target population of casualties with these injuries is approximately 1% of all MAIS 3+ surviving frontal impact casualties.

### *5.4.6 $N_1$ vehicles*

Because the only dataset with a suitable number of $N_1$ vehicle impacts recorded is the HVCIS fatals database, it is difficult to refine the target populations for $N_1$ vehicles further than was possible using the national accident data. The one fact that can be determined for fatalities in $N_1$ vehicles is the low seat belt wearing rate. Where it is known, the seat belt wearing rate for these fatalities was about 35% - much lower for fatalities in cars, where the seat belt wearing rate for fatalities was above 65%.

The analysis also showed that the majority of these $N_1$ vehicle fatalities were male (over 95%), and there were fewer elderly fatalities than were seen in cars.

Identifying $M_1$ vehicles which are not included in the current frontal impact legislation is difficult, as it requires knowledge of their maximum permitted gross vehicle weight – which is not recorded as standard in any of the in-depth databases.

# 6 Task 3: Detailed case analysis to investigate how well current Regulation 94 test represents real-world accidents

## 6.1 Introduction

The objective of this task was to perform detailed case analysis:

- To review fatal injury cases in Regulation 94 compliant (or equivalent) cars in frontal impacts to help understand the reasons why they were killed, to help guide future improvements to Regulation 94.
- To analyse the performance of vehicles involved in impacts similar to the Regulation 94 test to help understand how well this test represents real-world accidents to help guide future improvements to Regulation 94.

This task was performed using UK data only to minimise the total cost of the project.

Two groups of real-world impacts were investigated in detail, in order to determine how well the frontal impact Regulation 94 test represents what is important in real world accidents, and help identify any modifications which should be made to it. The first group of impacts investigated consisted of frontal impacts of Regulation 94 compliant cars where an occupant of that vehicle was fatally injured. The main purpose of this part of the work was to help determine why people are still dying in frontal crashes despite seat belt use, airbags and the crashworthy structures of modern vehicles. Each of the cases was examined in detail, and the primary and secondary factors which led to the fatally were determined. The methodology followed for this study was based on a similar study recently performed by NHTSA (Bean *et al*., 2009). The NHTSA study concluded that the primary reasons why people were still killed were:

- The crash was exceedingly severe
- There was poor structural engagement between the vehicle and its collision partner
- The occupants were exceptionally vulnerable.

The second group of impacts investigated consisted of frontal impacts of Regulation 94 compliant cars which were in accidents with a similar configuration to the Regulation 94 test. The outcome of each of these accidents was compared to the test results of a Euro NCAP frontal impact test with the same vehicle to determine whether or not the vehicle performed as expected and if not why not. It should be noted that ideally a comparison should have been made with the test results of a Regulation 94 test with the same vehicle. However, because these test results were not available and the Euro NCAP frontal impact test is similar to a Regulation 94 test with the exception that it has an higher test speed (64 km/h compared to 56 km/h), the Euro NCAP results were used instead.

## 6.2 Description of work

### *6.2.1 Fatalities in Regulation 94 compliant cars*

The CCIS database was interrogated to identify Regulation 94 compliant (or equivalent) cars involved in frontal crashes where at least one occupant in the vehicle was fatally injured. The full list of criteria used to identify these cases can be seen in Table 6-1. There were a total of 48 fatally injured occupants who met these criteria.

**Table 6-1. Selection criteria for case analysis of fatalities in Regulation 94 compliant cars**

| Variable | Criteria |
|---|---|
| Side of single significant impact | Front |
| Year of manufacture | >= 2000 and NOT unknown. Regulation 94 compliant only. |
| Rollover | None |
| Belt used? | Yes |
| Unbelted occupant behind? | No |
| Injury severity | Fatal |

Each of these cases was investigated in detail, and the primary and secondary factors which led to the fatality were defined and recorded by a team of accident investigators. The methodology and factors used for this study were based on a similar study recently performed by NHTSA (Bean et al., 2009).

The main factors defined were:

- Severe crash / anomaly
    - This factor was used when the severity of the accident was above that of the Regulation 94 test. It was divided into two sub-factors depending on the severity of the accident based on the estimate of the Equivalent Energy Speed (EES). These were 56 kph < EES < 65 kph and EES >= 65 kph to represent accidents that were slightly more severe than the Regulation 94 test and those that were much more severe than the Regulation 94 test, respectively. It was assumed that the EES of a Regulation 94 test lies somewhere between 50 and 56 kph. It should be noted that for one accident it was obvious that its severity was high but it was not possible to estimate the EES. This was classified as severe crash with an anomaly.
- Vulnerable occupant (Elevated occupant age)
    - This factor was used when the occupant was more likely to sustain a greater injury then would normally be expected because of his/her increased vulnerability to injury due to 'elevated age' (age 66+).
- Underride
    - This factor was used when there was poor engagement of the vehicle's main longitudinal structures in the vertical direction with its impact partner. It was divided into sub-factors which described the impact partner, e.g. HGV front, HGV rear, car front.
- Limited horizontal structural engagement
    - This factor was used when there was poor engagement of the vehicle's main longitudinal structures in the horizontal (lateral) direction with its impact partner. Generally this occurred in accidents with a small overlap. It was divided into sub-factors which described if it occurred with or without underride.

- Intrusion
    - This factor was used when intrusion of the occupant compartment led to the fatality. The location of the most significant intrusion was described, e.g. steering wheel, upper compartment. This factor was usually a secondary factor.
- External object
    - This factor was used when contact with an external object led to the fatality. This was often a secondary factor when underride with a HGV was the main factor.

#### *6.2.2 Impacts similar to current Regulation 94 test*

The CCIS database was interrogated to find vehicles which were involved in impacts similar to the Regulation 94 test, including occupants of all injury severities. The criteria used to select these cases are shown in Table 6-2. There were a total of 25 occupants in CCIS who met these criteria.

**Table 6-2. Criteria to select impacts similar to the Regulation 94 test for case analysis**

| Variable | Criteria |
|---|---|
| Side of single significant impact | Front |
| Year of manufacture | >= 2000 and NOT unknown. Regulation 94 compliant (or equivalent) only. |
| Rollover | None |
| Belt use? | Yes |
| Unbelted occupant behind? | No |
| Object hit | Car or LGV or wide object |
| Principle direction of force | 11, 12, OR 1 o'clock |
| Longitudinal loading | One longitudinal directly loaded |
| Overlap | >=20% AND <= 70% |
| | Impact to driver side or passenger side |
| Equivalent energy speed (EES) | >=45 kph AND <=56 kph |
| Model tested by Euro NCAP | Yes |

It should be noted that cases for analysis were selected for impacts with overlap to the driver or passenger side of the car, even though only the cases in which the impact was to the driver side of the car are strictly equivalent to the Regulation 94 test. The reason for this was that the structural performance of the car should be as good independent of which side of the car is impacted as vehicles can be supplied as left or right hand drive versions depending on which country they are to be used in.

Each of these cases was investigated in detail by a team of accident investigators. Based on the Euro NCAP test results, an assessment of the structural performance of the car and the occupant injuries in each accident case was made to determine whether they were "as expected or better than expected", "slightly worse than expected", or "worse than expected". If the occupant was fatally injured, the injury outcome was assessed as "worse than expected - fatal". If the structural performance of the car or injury outcome were assessed as "worse than expected", reasons why were determined.

For the assessment of the car's structural performance it was assumed that the structural performance seen in the Euro NCAP test was representative for impacts to either side of the car (i.e. driver or passenger). For the assessment of the occupant's injury the first step was an assessment of the compartment intrusion to side of the car on which the occupant was seated. This was then used as a basis for the assessment of the occupant's injury.

## 6.3 Findings

### *6.3.1 Fatalities in Regulation 94 compliant cars*

The primary factors which were recorded for the 48 fatally injured occupants are shown in Table 6-3. In this table the primary factors have also been grouped into "bins" of related factors.

**Table 6-3. Primary factors resulting in fatality of car occupants in Regulation 94 compliant cars**

| Primary factor bin | Primary factor | Number of casualties | |
|---|---|---|---|
| | | Primary | In bin |
| Severe crash / anomaly | EES > 65 kph | 11 | 17 |
| | 56 kph < EES <= 65 kph | 5 | |
| | Anomaly | 1 | |
| Vulnerable occupant | Elevated occupant age | 13 | 13 |
| Underride | HGV front | 4 | 10 |
| | HGV rear | 3 | |
| | LGV front | 1 | |
| | SUV front | 1 | |
| | Car front | 1 | |
| Limited horizontal structural engagement | With underride | 2 | 4 |
| | Without underride | 2 | |
| Other | Post crash fire | 2 | 4 |
| | Oblique impact | 1 | |
| | Unknown | 1 | |
| Total | - | 48 | 48 |

The most frequent primary factors are severe crashes, followed by occupants with elevated age and impacts involving underride. It should be noted that fatal accidents involving the elderly, and HGVs, are over-represented in CCIS compared to the national statistics (see Appendix A). However, even if the proportion of accidents was adjusted to match the national statistics, the order of the primary factor bins in Table 6-3 did not change.

Table 6-4 shows both the primary and secondary factors which were recorded for the 48 fatally injured occupants. Where intrusion was a secondary factor, the area of intrusion which was related to the most severe injuries is shown in brackets. Where there was a lot of intrusion to different areas of the vehicle, the steering wheel was often associated with the most severe injuries because the most severe injuries were often to the thorax.

**Table 6-4. Primary and secondary factors resulting in fatality of car occupants in Regulation 94 compliant cars**

| Primary factor bin | Primary factor | Secondary factor | Number of casualties | | |
|---|---|---|---|---|---|
| | | | Secondary | Primary | In bin |
| Severe crash / anomaly | EES > 65 kph | Intrusion (steering wheel) | 5 | 11 | 17 |
| | | Compatibility (minibus) | 2 | | |
| | | No secondary factor | 2 | | |
| | | Elevated occupant age | 1 | | |
| | | Underride (LGV front) | 1 | | |
| | 56 kph < EES <= 65 kph | Intrusion (steering wheel) | 3 | 5 | |
| | | Compatibility (car) | 1 | | |
| | | Intrusion (upper compartment) | 1 | | |
| | Anomaly | Underride (HGV rear) | 1 | 1 | |
| Vulnerable occupant | Elevated occupant age | No secondary factor | 9* | 13 | 13 |
| | | Anomaly | 1 | | |
| | | Obese occupant | 1 | | |
| | | Small stature | 1 | | |
| | | Severe crash (56 kph < EES <= 65 kph) | 1 | | |
| Underride | HGV front | Elevated occupant age | 1 | 4 | 10 |
| | | External object | 1 | | |
| | | Intrusion (facia) | 1 | | |
| | | Intrusion (upper compartment) | 1 | | |
| | HGV rear | External object | 2 | 3 | |
| | | Guard did not prevent underride | 1 | | |
| | LGV front | Intrusion (facia) | 1 | 1 | |
| | SUV front | Sitting too far forward | 1 | 1 | |

| Primary factor bin | Primary factor | Secondary factor | Number of casualties | | |
|---|---|---|---|---|---|
| | | | Secondary | Primary | In bin |
| | Car front | Intrusion (steering wheel) | 1 | 1 | |
| Limited horizontal structural engagement | With underride | Underride (bus front) | 1 | 2 | 4 |
| | | Underride (HGV front) | 1 | | |
| | Without underride | Intrusion (steering wheel) | 1 | 2 | |
| | | Intrusion (upper compartment) | 1 | | |
| Other | Post crash fire | Severe crash (EES > 65 kph) | 1 | 2 | 4 |
| | | Severe crash (56 kph < EES <= 65 kph) | 1 | | |
| | Oblique impact | Elevated occupant age | 1 | 1 | |
| | Unknown | No secondary factor | 1 | 1 | |
| Total | - | | 48 | 48 | 48 |

*Note: In 6 cases the vulnerable occupant had a severe thorax injury related to the seatbelt

Intrusion was often a secondary factor in high severity crashes and in crashes where there was poor engagement of the vehicle structure (either because of underride or limited horizontal structural engagement). When the primary factor was elevated occupant age, secondary factors most frequently involved injury related to the restraint system, and in some cases there were no secondary factors recorded. These were often low severity crashes, where the only injuries were related to the restraint system, or where there was no obvious reason why the injuries received were fatal except the elevated age of the occupant.

### *6.3.2 Impacts similar to current Regulation 94 test*

Table 6-5 summarises the results of the study to assess the outcome of accidents with a configuration similar to the Regulation 94 test based on the results of a Euro NCAP frontal impact test. Each of these cases was investigated in detail by a team of accident investigators. Based the Euro NCAP test results, an assessment of the structural performance of the car and the occupant injuries in each accident case was made to determine whether they were "as expected or better than expected", "slightly worse than expected", or "worse than expected". If the occupant was fatally injured, the injury outcome was assessed as "worse than expected - fatal". If the structural performance of the car or injury outcome were assessed as "worse than expected", reasons why were determined.

**Table 6-5. Comparison of accident outcomes to that expected based on Euro NCAP test**

| Structural performance | Intrusion | Injury outcome | Number of casualties | | |
|---|---|---|---|---|---|
| | | | Injury | Intrusion | Structural |
| As expected / better | None | As expected / better | 6 | 10 | 16 |
| | | Slightly worse than expected | 4 | | |
| | Low | As expected / better | 2 | 3 | |
| | | Slightly worse than expected | 1 | | |
| | Medium | As expected / better | 2 | 2 | |
| | Large | As expected / better | 1 | 1 | |
| Slightly worse than expected | Medium | Slightly worse than expected | 1 | 1 | 1 |
| Worse than expected | Low | As expected / better | 1 | 1 | 8 |
| | Medium | Worse than expected | 1 | 2 | |
| | | Worse than expected - fatal | 1 | | |
| | Large | As expected | 2 | 5 | |
| | | Worse than expected | 1 | | |
| | | Worse than expected - fatal | 2 | | |
| Total | - | - | 25 | 25 | 25 |

Of the 25 occupants, 16 were in a vehicle where the structural performance was as expected or better, which suggests that the test gives a reasonable representation of real world structural performance in the majority of cases. However, there were 8 vehicles where the structural performance was worse than expected – the possible reasons for the poor structural performance of these vehicles are summarised in Table 6-6. Most of these reasons identified were related to poor compatibility or structural interaction.

**Table 6-6. Reasons that structural performance was worse than expected**

| Structural performance | Reason | Frequency |
|---|---|---|
| Worse than expected | Possible compatibility issue (poor structural interaction) | 3 |
| Worse than expected | Possible compatibility issue (poor structural interaction / low overlap) | 2 |
| Worse than expected | Poor structural interaction (low overlap) | 1 |
| Worse than expected | Overridden by SUV, large mass difference | 1 |
| Worse than expected | EES possibly an underestimate | 1 |

Amongst these cases there were examples of car-to-car impacts where the longitudinals did not perform in the way they were seen to perform in the test. An example of this is shown in Figure 6-1. The vehicle of interest is shown on the left, and the driver of this vehicle was killed. This vehicle was involved in a head on impact with another similar vehicle, but there was poor structural interaction and the nearside longitudinal in the vehicle of interest did not crush as it did in the Euro NCAP test. Because it did not crush in the designed manner, the energy absorption capability of the vehicle's front-end was reduced which contributed to a poorer crash performance of the car than expected based on the Euro NCAP test result.

**Figure 6-1. Example of car-car impact where the longitudinal did not crush as in the test**

One of the underlying reasons for this is that the current Offset Deformable Barrier (ODB) test does not reproduce well the front-end structural loading and resulting deformation seen in a car-to-car crash. This is because in the current ODB test most vehicles 'bottom out' the barrier face and hence can use the rigid wall behind the barrier to help collapse their main frontal longitudinal structures. In a car-to-car impact this 'rigid wall' is not present and hence if the car's main longitudinal structures are not well connected so that the load can be spread over a large surface, the car's longitudinals will penetrate the structure of the opposing car, because there is no 'rigid wall' to interact with, and not collapse as in the ODB test. The result of this is a reduction in the energy absorption capability of the front-end of the car which will lead to passenger compartment intrusion in severe crashes when a large energy absorption capability is needed. This is a known problem and one of the reasons for the proposal by France to change Regulation 94 to replace the current ODB test with a Progressive Deformable Barrier (PDB) test (GRSP, 2007). The PDB barrier face is deeper and stiffer than the current ODB barrier face to prevent vehicles being able to 'bottom out' the barrier face and use the 'rigid wall' to collapse their main longitudinal structures. This enables the PDB test to reproduce better the deformation observed in a car-to-car crash (Delannoy *et al*. 2005, VC-COMPAT 2006). An example of how the longitudinals of a supermini car deform differently in a PDB test compared to an ODB test is shown in Figure 6-2.

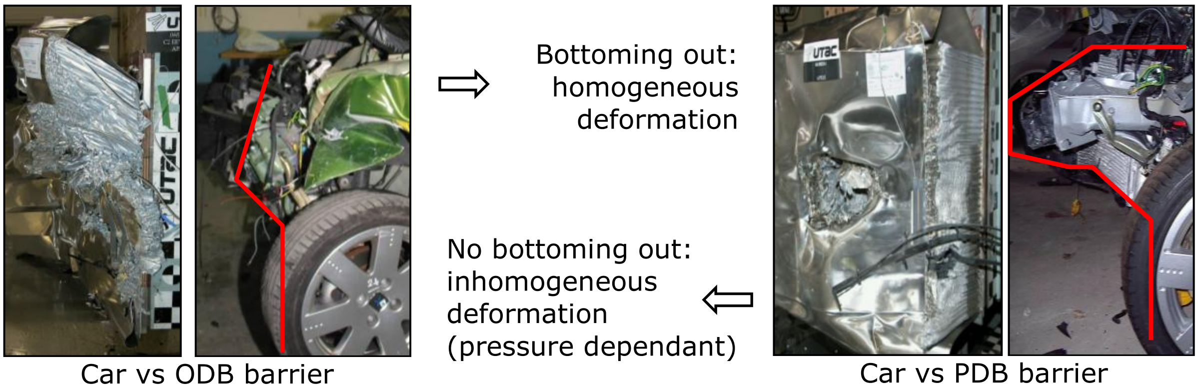


**Figure 6-2. Comparison of the deformation of the barrier and car in the current ODB test and a PDB test showing difference in performance of longitudinal**

The injury outcome was as expected or better than expected for 14 of the 25 occupants. However, as with structural performance, there are a significant number of casualties where the injury outcome was slightly worse than expected or worse than expected based on the Euro NCAP test results.

There were six occupants where the injury outcome was slightly worse than expected – these often involved a single AIS 2+ injury (usually a fracture) in a body region that the Euro NCAP test suggested was adequately protected. In addition to these occupants, there were 5 whose injury outcome was worse than expected. 3 of these were actually fatally injured. Table 6-7 summarises the possible reasons why these occupants received worse injuries than were expected based on the results of the Euro NCAP test. These are mainly related to the large amount of intrusion into the passenger compartment, caused by poor structural performance of the car, which in turn was related to issues of poor compatibility and structural interaction.

**Table 6-7. Reasons that injury outcome was worse than expected**

| Injury outcome | Reason | Frequency |
|---|---|---|
| Worse than expected | Large intrusion – compatibility issue (poor structural interaction / low overlap) | 1 |
| Worse than expected | Medium intrusion – poor structural interaction (low overlap) | 1 |
| Worse than expected - fatal | Large intrusion – overridden by SUV | 1 |
| Worse than expected - fatal | Large intrusion – EES possibly an underestimate | 1 |
| Worse than expected - fatal | Medium intrusion – possible compatibility issue, age of occupant | 1 |

For completeness the characteristics of the group of accidents analysed are shown below.

Figure 6-3 shows the distribution of EES for the occupants selected in impacts similar to the Regulation 94 test. It appears that there is a disproportionate number of impacts at an EES of 56 kph. However, because of the small sample size, the variations in the distribution of EES are not statistically significant.

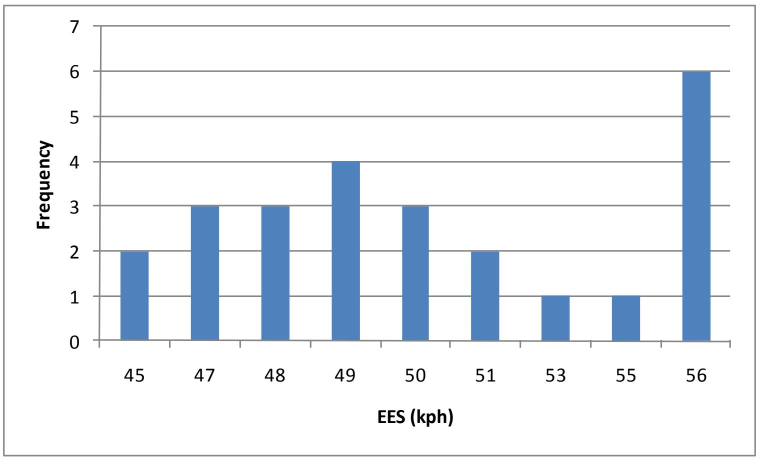


**Figure 6-3. Distribution of EES in cases similar to Regulation 94 test**

Figure 6-4 shows the distribution of age and gender for the occupants selected. Interestingly, there are very few elderly occupants in this sample compared to the sample of fatally injured occupants.

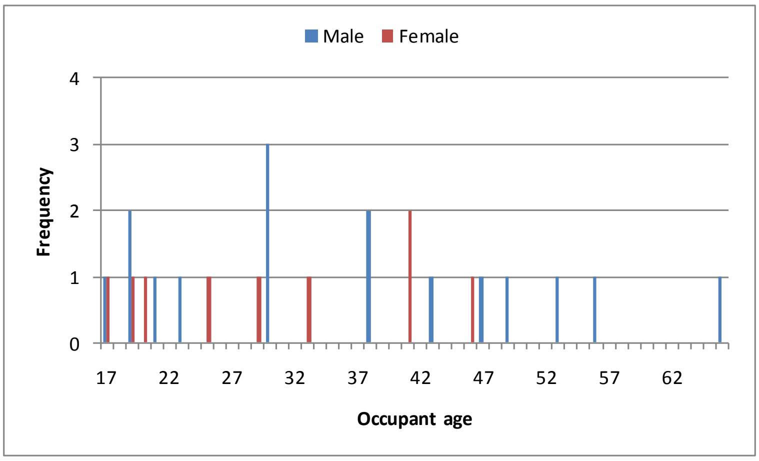


**Figure 6-4. Distribution of age and gender of occupants in impacts similar to Regulation 94 test**

## 6.4 Summary of findings and regulatory implications

### *6.4.1 Fatalities in Regulation 94 compliant cars*

48 fatalities in Regulation 94 compliant cars were selected from the GB CCIS database and investigated in detail to help determine why people are still dying in frontal crashes despite seat belt use, airbags and the crashworthy structures of modern vehicles. Based on the methodology used by a similar study performed recently b NHTSA (Bean *et al*., 2009) primary and secondary factors were determined explaining why the accident was fatal. The results of this analysis were as follows:

- The most frequent primary factor recorded was the high severity of the crash. Some of these crashes had a severity slightly above that of the Regulation 94 test (56 kph < EES <= 65 kph) and could possibly be addressed by an increase in the test severity but the majority had a severity substantially above that of the

Regulation 94 test (65kph < EES) and it is unlikely that they could be addressed by changes to the Regulation 94 test.

- The second most frequent primary factor was the vulnerability of the occupant due to elevated age (66+). This was also a frequent secondary factor. Some occupants were sufficiently fragile that even a low severity crash was enough to cause fatal injuries. This highlights the importance of considering potential changes for Regulation 94 to improve protection for the elderly.
- Other frequent primary factors were underride and limited horizontal structural engagement, i.e. factors related to compatibility. The majority of cases with these primary factors were impacts with Heavy Goods Vehicles (HGVs), where the performance of the underride protection (if present) was a key parameter. However, some of them were impacts with other cars, or Light Goods Vehicles (LGVs) which potential changes to Regulation 94 to improve car-to-car frontal impact compatibility could help address.
- Intrusion was often cited as a secondary factor and often related to severe impacts or compatibility problems.

### *6.4.2 Impacts similar to current Regulation 94 test*

25 occupants of Regulation 94 compliant cars involved in impacts similar to the Regulation 94 test were identified in the GB CCIS database. Each of these cases was investigated in detail by a team of accident investigators. Based the Euro NCAP test results, an assessment of the structural performance of the car and the occupant injuries in each accident case was made to determine whether they were "as expected or better than expected", "slightly worse than expected", or "worse than expected". If the occupant was fatally injured, the injury outcome was assessed as "worse than expected - fatal". If the structural performance of the car or injury outcome were assessed as "worse than expected", reasons why were determined. The results of the assessment were as follows:

- In just over half of cases, the car's structural performance and injury outcome in the accident was assessed as "as expected or better" based on the results of the Euro NCAP test. However, there were a significant number of cases where the structural performance or injury outcome was assessed as "worse than expected".
- The injury outcome was only assessed as "worse than expected" when the car's structural performance was also assessed as "worse than expected". In these 5 cases the reasons determined for the "worse than expected" injury outcome were related to the large amount of intrusion into the passenger compartment, which was caused by poor structural performance of the car, which in turn was related to issues of poor compatibility and structural interaction. This highlights the importance of considering potential changes to Regulation 94 to improve a vehicle's compatibility and structural interaction potential.

# 7 Task 4: Compatibility

## 7.1 Introduction

The objective of this task was to understand the nature and magnitude of the compatibility problem in frontal impacts to help determine the importance of taking compatibility effects into account for potential changes to Regulation 94.

Compatibility consists of self and partner protection. In vehicle-to-vehicle collisions improved compatibility will result in a reduced overall injury risk for all occupants and more similar injury risks for the occupants of both the light and heavy vehicles. Compatible vehicles will deform in a stable manner allowing the deformation zones to be exploited even when different vehicle sizes and masses are involved.

## 7.2 Description of work

The analysis performed consisted of three parts. The first part focused on partner protection and determined an aggressivity ratio for different classes of vehicle (e.g. SUVs, small cars, large cars, etc) by comparing the severity of the casualty's injuries in the two vehicles. The second part focused on self-protection and determined the "severity proportion" (proportion of casualties who were killed or seriously injured) for vehicles by vehicle weight, adjusting for gender, age, etc. The third and final part investigated the relationship between mass ratio of the vehicles involved in the impact and injury severity of the drivers in the vehicles.

The majority of the analysis concentrated on impacts between two Regulation 94 compliant cars to ensure that the results were representative of the performance of Regulation 94 compliant vehicles and hence appropriate for use to set priorities for an update of Regulation 94. However, how the situation is different for Regulation 94 compliant cars compared to non-Regulation compliant cars, and how the aggressivity of Light Goods Vehicles (LGVs) compares to Regulation 94 compliant cars, were also investigated.

In order to put the analysis in context, the mass distributions in the fleet and the accident samples from the different countries were compared. This comparison is shown in Appendix D.

### *7.2.1 Aggressivity – partner protection*

The "aggressivity" metric was used to investigate the relationship between vehicle mass and its partner protection. This was defined by Gabler and Hollowell (1998) as follows:

$$Aggressivity = \frac{Driver\ fatalities\ in\ collision\ partner}{Number\ of\ crashes\ of\ subject\ vehicle}$$

Because this measure uses the number of fatalities, it is best calculated with a large dataset (because there are relatively few fatalities compared to occupants of other injury severity). For this reason, this analysis was performed using the national accident data of Great Britain, Germany, and France.

The aggressivity was compared for three different samples in each dataset. The first sample was all ages of vehicle hitting all ages of vehicle. The second sample was for Regulation 94 compliant vehicles hitting all ages of vehicle. The third sample was for Registration 94 compliant vehicles hitting other Regulation 94 compliant vehicles.

This analysis was performed for cars in front-front impacts in France and Germany, and cars and LGVs in frontal impacts in Great Britain. Regulation 94 compliant vehicles were selected as described in section 3. LGVs were selected based on the date they were first registered – LGVs registered in October 2003 or later were analysed at the same time as Regulation 94 compliant cars, to see whether new vehicles which were not covered by the Regulation had different values of aggressivity.

In Great Britain and Germany the results were broken down by vehicle type for comparison. In Germany and France the results were broken down by vehicle mass for comparison. The vehicle types in Great Britain are chosen subjectively based on the body style of the vehicle, and are not the same as the vehicle types in the German national data. In the German data, the vehicle types are marketing categories, which are provided by the manufacturer.

It was not possible to compare the aggressivity with vehicle mass for Great Britain because the national data did not contain a high enough proportion of vehicles where the mass was recorded.

### *7.2.2 Severity proportion – self protection*

The measure used to explore the relationship between self protection and vehicle mass was the severity proportion. Two slightly different definitions of the severity proportion were used in the analysis, one of which only uses injured drivers, the other uses all drivers involved in crashes:

$$Severity\ proportion = \frac{Fatal + Serious\ drivers}{Fatal + Serious + Slight\ drivers}$$

$$Severity\ proportion = \frac{Fatal + Serious\ drivers}{Fatal + Serious + Slight + Uninjured\ drivers}$$

The analysis of severity proportion was performed using the national data from Great Britain, France, and Germany. The national data for France and Germany contains information about the mass of the vehicle, so the severity proportion was calculated for vehicle masses in groups of 1000 kg. The two different measures of severity proportion were used to look at two different types of accident: front-front car-car impacts between two Regulation 94 compliant cars, and frontal impacts of one Regulation 94 compliant car in a single vehicle accident. It should be noted that the national data in Germany could not identify frontal impacts in single vehicle accidents.

The expectation of this analysis was that the severity proportion for single vehicle impacts would be constant with the mass of the vehicle, but the severity proportion for vehicle to vehicle crashes would decrease as the mass of the vehicle increased. This is because it was expected that in an impact between a lighter vehicle and a heavier vehicle, the occupants of the lighter vehicle would be more likely to receive fatal or serious injuries – the compatibility problem.

For the national data from Great Britain the mass of the vehicles had to be added individually for every make and model because it is not often recorded in the national data. This limited the number of vehicles with mass information, so the severity proportion for Great Britain could only be calculated for car to car impacts where only one of the vehicles had to be Regulation 94 compliant. The make, model, registration year, and vehicle type was used to look up the mass of the vehicles from a number of sources (including Glass's Guide (2006) and Parker's (2010)). The kerb mass was used, which does not take into account any increase in mass due to the mass of the occupants or luggage.

It should be noted that there are a number of limitations of using the severity proportion to ascertain the self protection of a group of vehicles. There are many confounding factors which have not been taken into account in this analysis which could be affecting the results, such as type of driver and impact severity. There are other types of analysis, such as paired analysis, which may be able to account for these differences.

The data from Great Britain and Germany was also adjusted to remove the confounding factors of age, gender, and the location of the accident (urban or rural). This was performed using regression to determine the relationship between the different factors and the severity ratio, then adjusting for this relationship. This action was performed on groups of vehicles which had the same mass, as long as at least 30 injured drivers were contained within each group.

#### 7.2.3 Mass ratio

The mass ratio of the frontal impacts in the different datasets was examined to determine the relationship between the mass ratio and injury severity, and the distribution of mass ratios which occur in frontal car-to-car impacts. The mass ratio for each vehicle involved in a frontal impact was calculated as follows:

$$Mass\,ratio = \frac{Mass\,of\ other\,vehicle}{Mass\,of\ vehicle\,containing\,driver}$$

The analysis of mass ratio is split into two sections. The first section explores the relationship between mass ratio and injury severity, using the in-depth accident data from Great Britain and the national accident data from France. The second section looks at the cumulative mass ratio distribution, and uses mainly the French national accident data.

### 7.3 Findings

#### 7.3.1 Aggressivity – partner protection

Figure 7-1 shows the aggressivity of the vehicles in the national data for Great Britain by vehicle type, which is based on the body style of the vehicle. It should be noted that in this figure the LGVs are $N_1$ vehicles.

This shows that the aggressivity is highest for the sample involving cars registered in October 2003 or later hitting all ages of car. However, when two of these newer cars hit each other, the aggressivity is much lower. This figure also shows a general trend of increasing aggressivity as the size of the vehicle increases; however, this trend is less clear for the sample of newer cars hitting newer cars. In this sample the aggressivity of Light Goods Vehicles (LGVs) which are classified as $N_1$ vehicles is also very low, even though these vehicles do not have to comply with Regulation 94. This suggests that improvements in the self protection of the impact partner (likely to be a car) may have reduced the number of fatalities in impacts with LGVs assuming that no improvements have been made to the aggressiveness of LGVs which is unlikely because there have been no regulatory changes or consumer tests to encourage them.

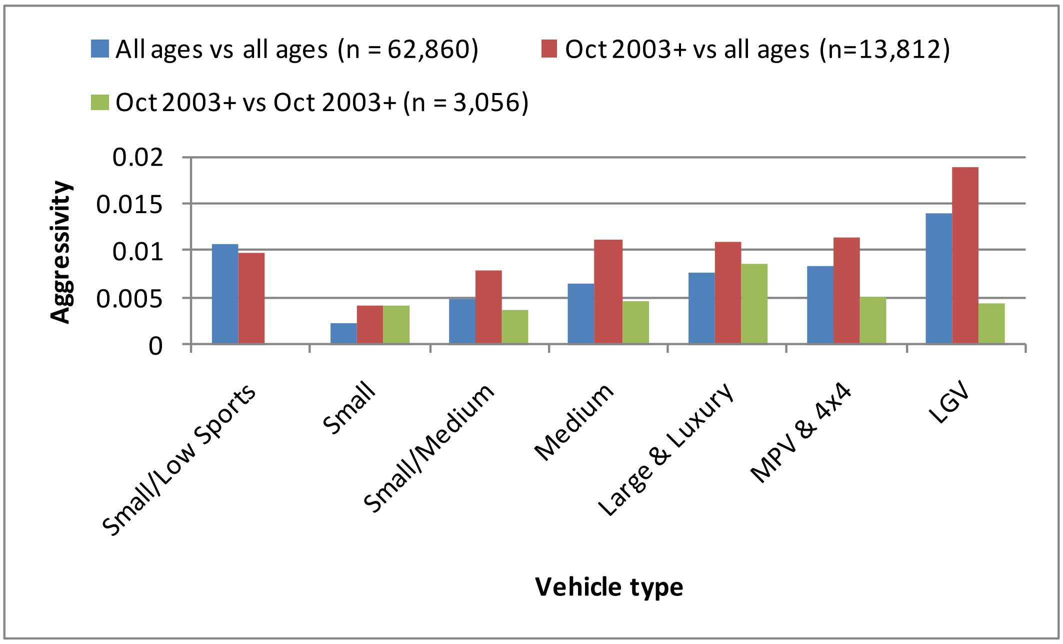


**Figure 7-1. Vehicle aggressivity calculated using national data for Great Britain split by vehicle type**

Figure 7-2 shows the vehicle aggressivity calculated from the German national data split by vehicle type. This shows a similar increasing relationship between aggressivity and vehicle size as was seen for Great Britain. It also shows that the aggressivity is highest for Regulation 94 cars hitting all ages of car. However, although the aggressivity does decrease for Regulation 94 cars hitting Regulation 94 cars, for many vehicle types it is still higher than it was for all cars hitting all cars. It should be noted that these vehicle types are marketing categories provided by the manufacturers, so cannot be compared to the vehicle types in Great Britain. All of these vehicle types are $M_1$ vehicles, including "Van".

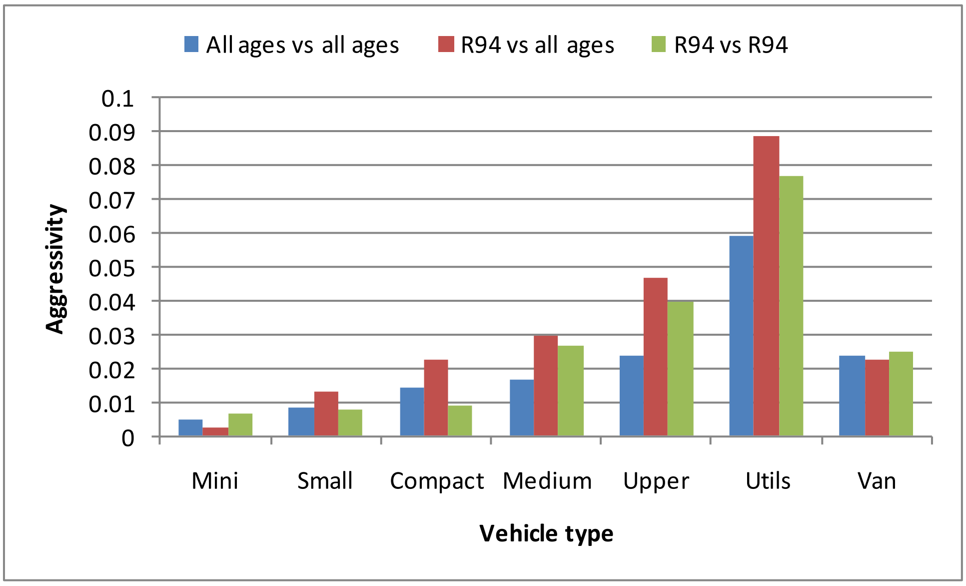


**Figure 7-2. Vehicle aggressivity from national data in Germany split by vehicle type**

Figure 7-3 shows the same information for Germany, but split using vehicle mass. This shows the same characteristics as the previous figure which was split by vehicle type.

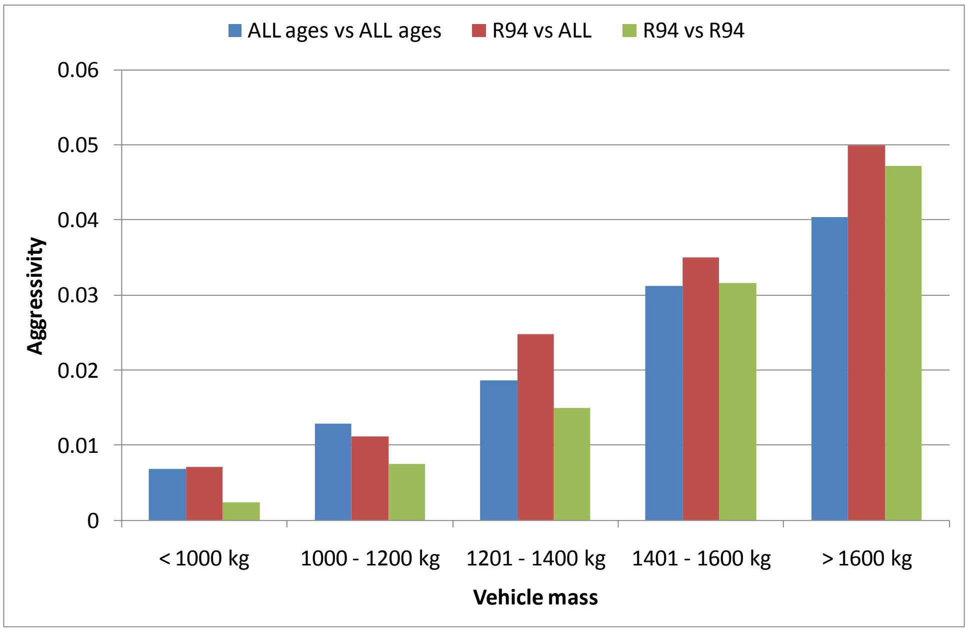


**Figure 7-3. Vehicle aggressivity from national data in Germany split by vehicle mass**

Figure 7-4 shows the vehicle aggressivity calculated from the French national data. This shows a similar pattern to the data from Great Britain: the vehicle aggressivity is highest for the newer cars hitting all ages of car, and is lowest for the newer cars hitting newer cars.

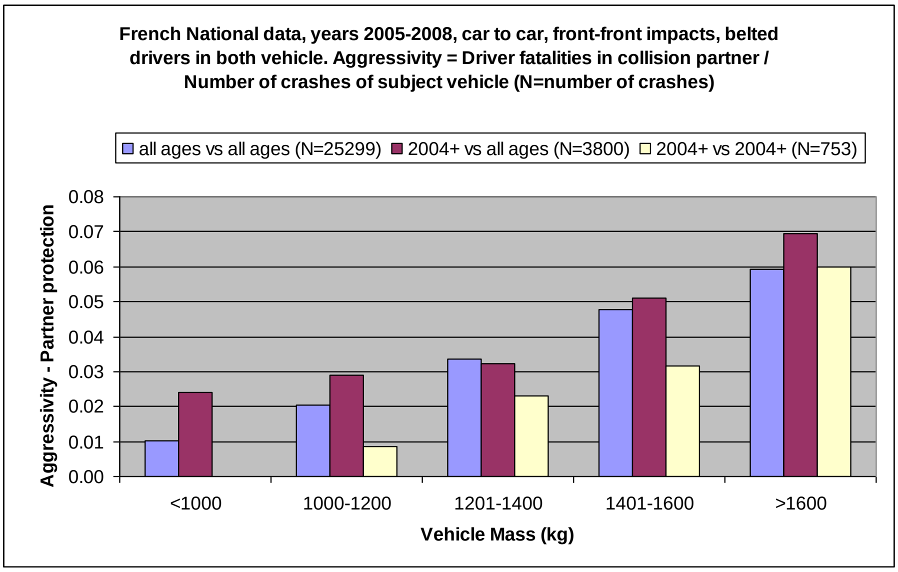


**Figure 7-4. Vehicle aggressivity from national data in France split by vehicle mass**

In summary, the above figures show that heavier vehicles are more aggressive. However, the mass distributions in Appendix D show that the majority of vehicles in the fleet have a mass under 1400kg, so the aggressivity of the majority of vehicles is relatively low.

The highest aggressivity occurs for Regulation 94 compliant cars in impacts with all ages of vehicle – this then reduces when both vehicles are compliant with Regulation 94.

There are some differences between the three countries – such as in Germany impacts between two Regulation 94 compliant vehicles have a higher aggressivity than impacts with two vehicles of any age. However, this difference could be caused by confounding factors such as the age of the occupants involved or the severity of the impacts.

### *7.3.2 Severity proportion – self protection*

#### *7.3.2.1 Regulation 94 compliant cars only*

Figure 7-5 shows the severity ratio calculated from the French national data, for front-front impacts involving Regulation 94 compliant cars. Calculating the severity ratio including only injured drivers shows very little change of severity ratio with mass. When uninjured drivers are included in the calculation, there is a slight decrease in the severity ratio as the mass of the vehicle increases.

Figure 7-6 shows the severity ratio calculated from the French national data for Regulation 94 cars in frontal impacts with an object in single vehicle accidents. This again shows very little change of severity ratio with mass.

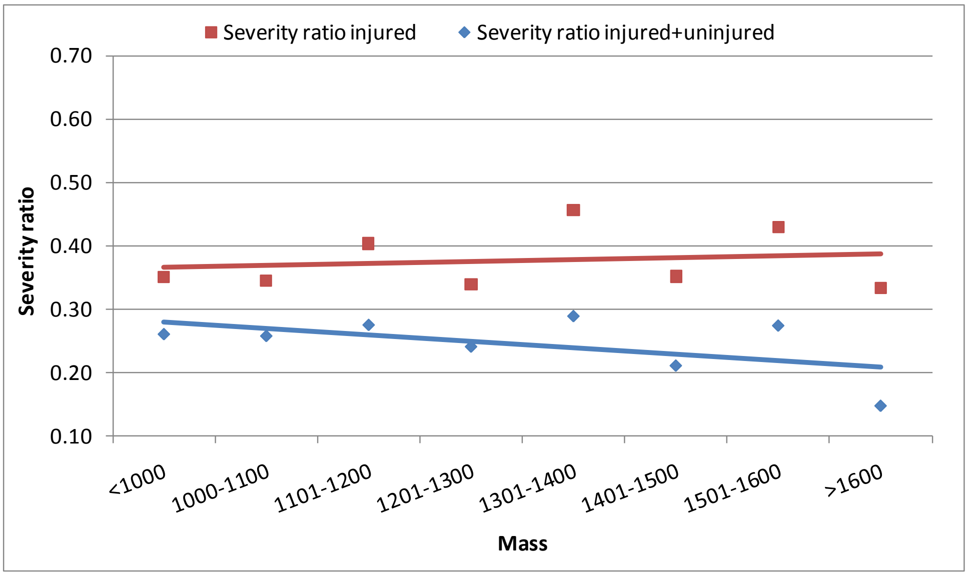


**Figure 7-5. Severity ratio for R94 vs R94 impacts, from French national data**

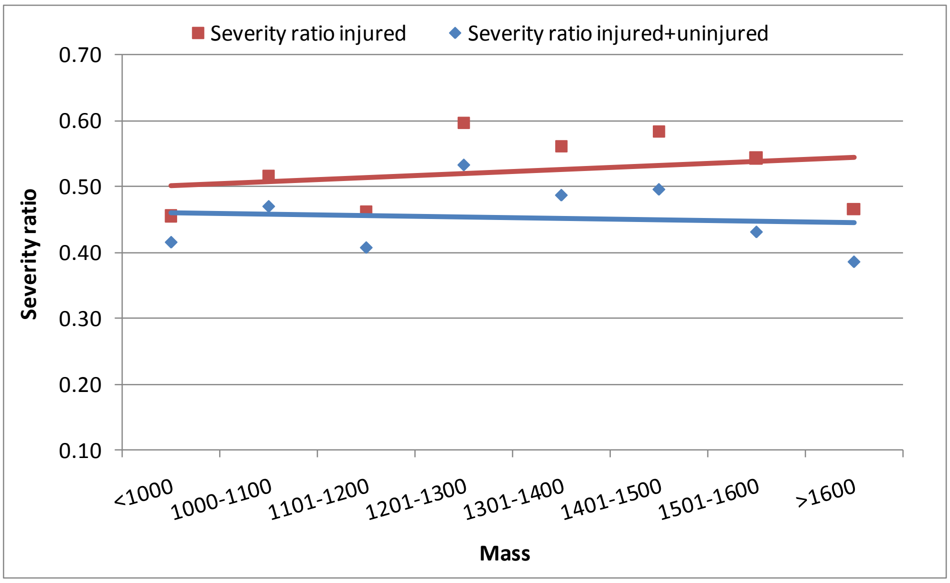


**Figure 7-6. Severity ratio for single vehicle R94 impacts, from French national data**

Figure 7-7 shows the relationship between severity ratio and mass calculated using the German national data, for front-front impacts involving two Regulation 94 compliant cars. This shows that the severity ratio decreases as the mass of the vehicle increases, up to a mass of about 1400kg. This trend is seen for both definitions of severity ratio. The mass distributions shown in Appendix D show that the majority of vehicles in the fleet, and the majority of vehicles in frontal impacts have a mass less than 1400kg, so this trend covers the majority of vehicles in Germany.

It should be noted that the magnitude of the severity ratio is different for France and Germany – the severity ratio is generally higher in France than in Germany. This is related to the level of reporting of slight casualties – more slightly injured drivers are recorded in Germany, therefore the calculated severity ratio is lower.

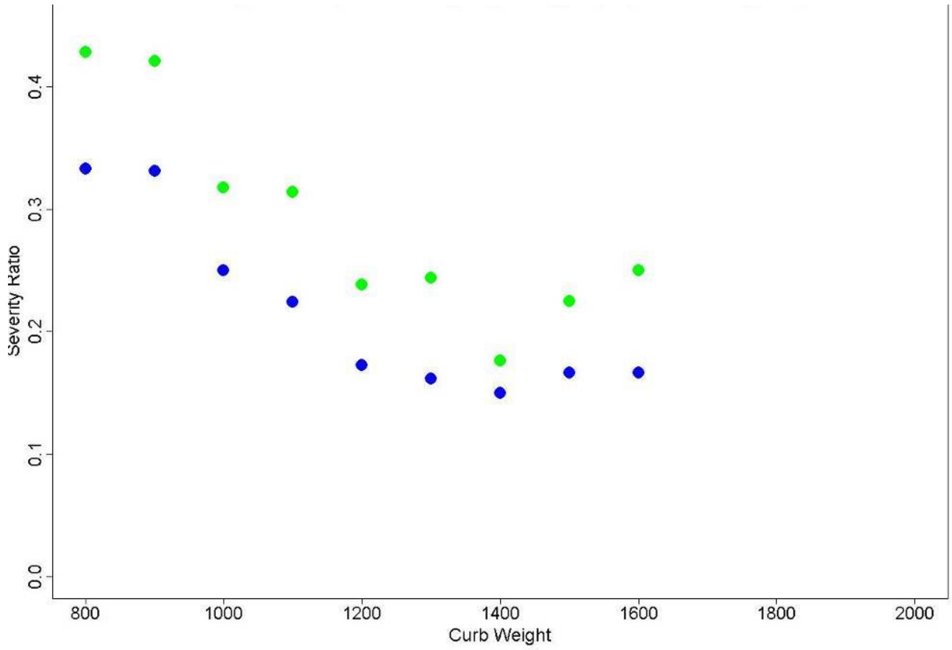


**Figure 7-7. Severity ratio for R94 vs R94 impacts, from German national data (green = injured drivers only, blue = injured+uninjured drivers)**

*7.3.2.2 Regulation 94 cars vs all cars*

Mass information was added to the national data of Great Britain by looking up the mass of the most popular makes and models featured in the database. This meant that the sample size available was not large enough to investigate severity ratio for impacts involving two Regulation 94 compliant cars, however it was large enough to look at Regulation 94 compliant cars having an impact with any age of car. The relationship between mass and severity ratio for this sample are shown in Figure 7-8. This shows little change in severity ratio with vehicle mass.

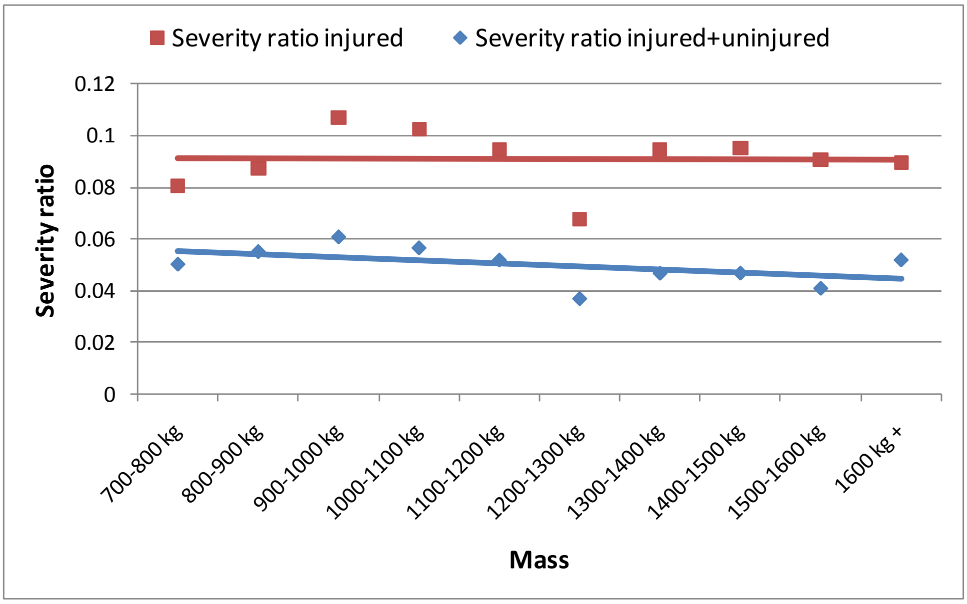


**Figure 7-8. Severity ratio for R94 vs all car impacts, using national data from Great Britain**

This data sample from the national accident data from Great Britain was also adjusted using a regression process to account for differences in age, gender, and location of the accident. Figure 7-9 shows the results of adjusting the severity ratio (for injured drivers only) to correspond to a 30 year old male driver in a crash on an urban road. Each point on the graph shows a group of vehicles of the same mass (the mass categories were not used because the individual masses were required for the regression analysis). Only groups containing at least 30 injured drivers are included in the figure. The adjustment made very little difference to the results, because the regression found there to be very little relationship between the severity ratio and age, gender, or location of accident.

Figure 7-10 shows a similar adjustment made to the same data sample, this time using the severity ratio that includes injured and uninjured drivers. Again, the adjustment to a 30 year old male driver had a very small effect on the results. In both of these figures there is no consistent increase or decrease of severity ratio with vehicle mass, and there is a large variation in severity ratio even for cars of similar mass. This suggests that there are factors more important than vehicle mass which have an effect on the severity ratio which cannot be taken into account using this data – such as the severity of the impact.

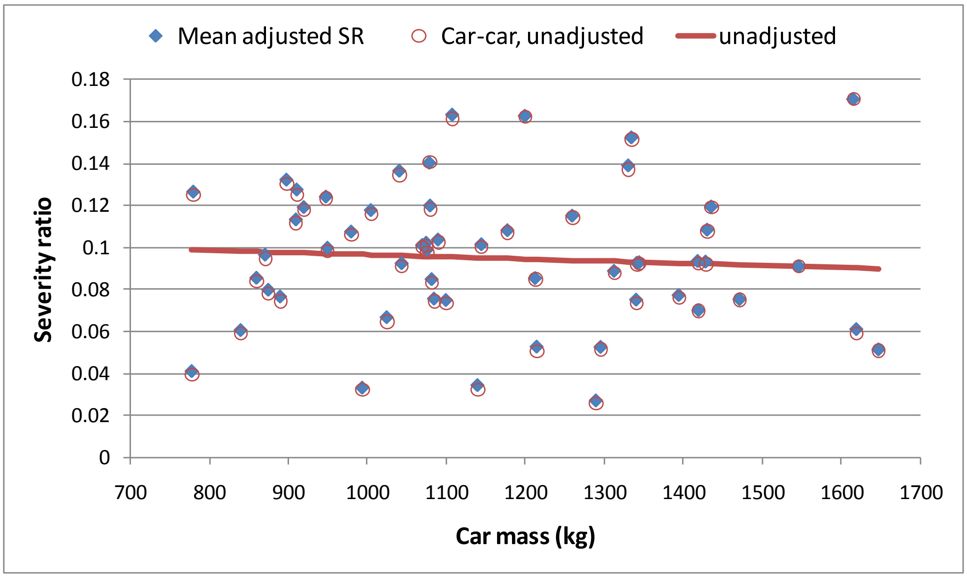


**Figure 7-9. Adjusting severity ratio by regression, using national data from Great Britain. Severity ratio including injured drivers only. R94 vs all cars.**

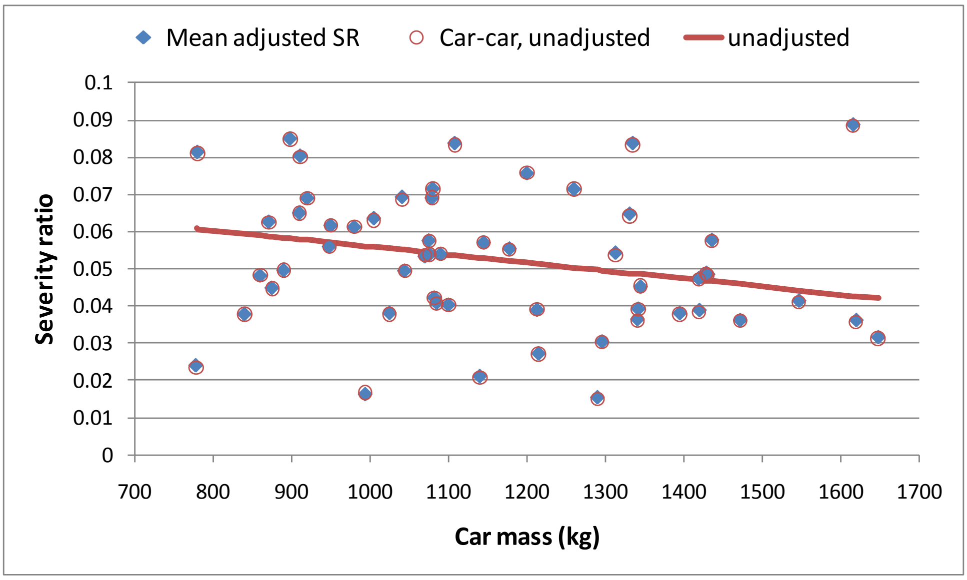


**Figure 7-10. Adjusting severity ratio by regression, using national data from Great Britain. Severity ratio including injured+uninjured drivers. R94 vs all cars.**

Figure 7-11 uses regression in a similar way to determine the relationship between mass and severity ratio for the German national data, adjusting the results to correspond to a 25-44 year old male. The figure shows two curves, one adjusted for impacts in an urban area, the other adjusted for drivers in a rural area. Figure 7-12 shows the same information for the severity ratio calculated using injured and uninjured drivers. Both of these figures show that the severity ratio decreases as the mass increases, a trend that can be seen both before and after the adjustment.

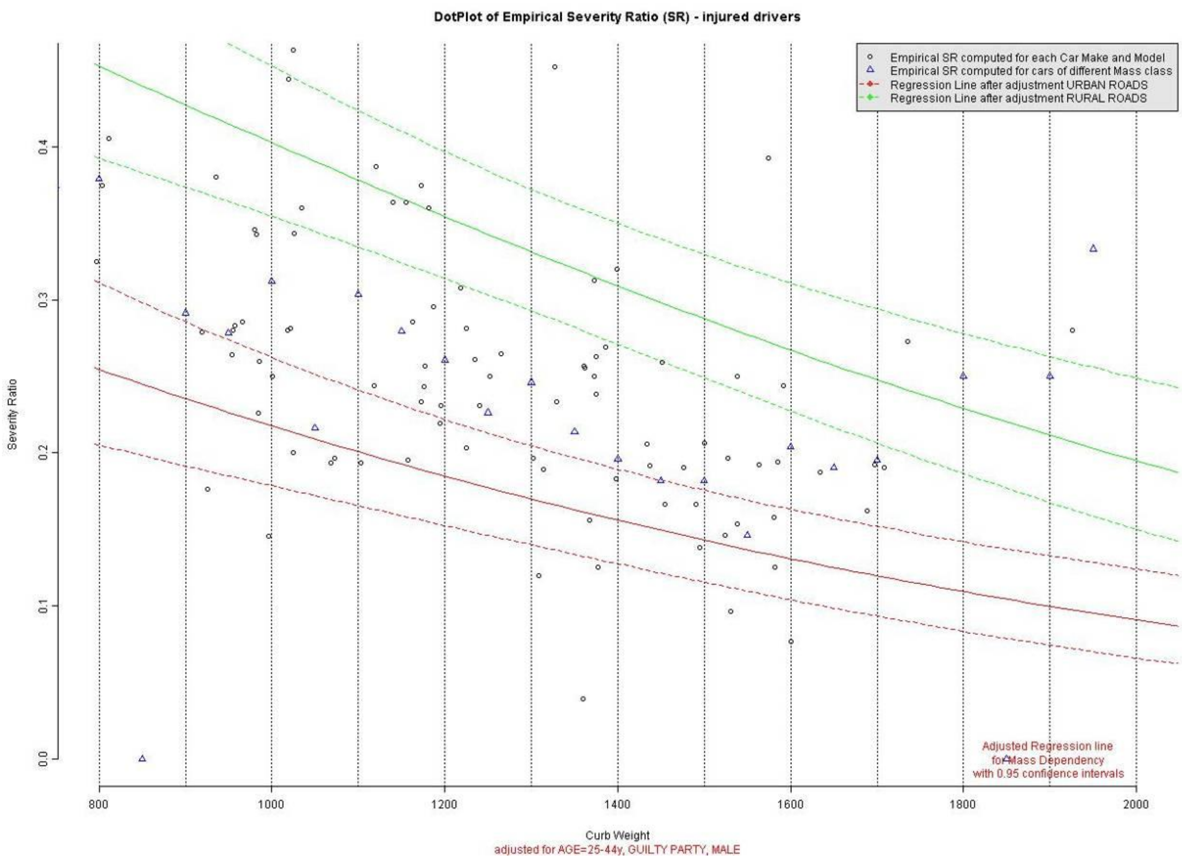


**Figure 7-11. Relationship between mass and severity ratio of injured drivers from German national data, adjusting for age, gender, and location (green = rural, red = urban). R94 vs all cars.**

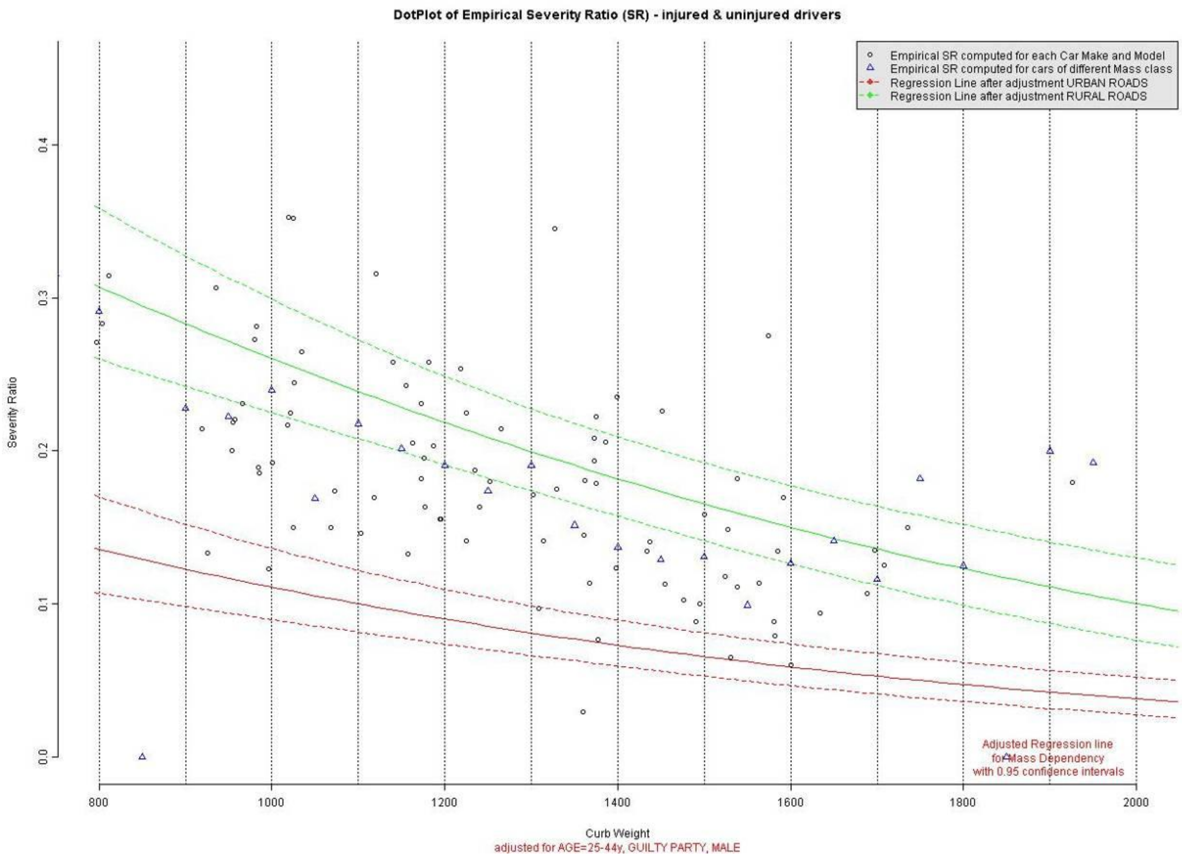


**Figure 7-12. Relationship between mass and severity ratio of injured+uninjured drivers from German national data, adjusting for age, gender, and location (green = rural, red = urban). R94 vs all cars.**

### *7.3.3 Mass ratio*

#### *7.3.3.1 Relationship between mass ratio and injury severity*

Figure 7-13 shows the proportion of vehicle frontal impacts of a given mass ratio which resulted in fatal, MAIS 3+, MAIS 2, or other injury. This figure was created using the in-depth CCIS database for Great Britain, using the same sample of Regulation 94 compliant vehicles used for all the in-depth analysis in Task 2. Although the sample size for this figure is relatively small, it does suggest that as the mass ratio increases the rate of the most serious and fatal injuries increases.

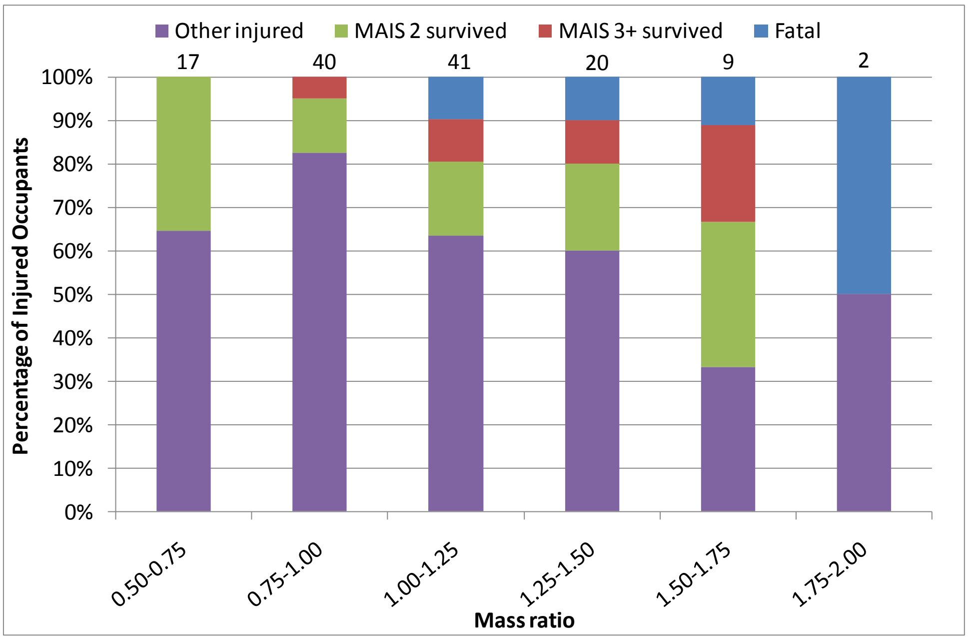


**Figure 7-13. Relationship between mass ratio and injury severity for Great Britain (from CCIS)**

Figure 7-14 shows the same information for the vehicles in the French national data. This shows that the rate of serious injury increases up to a mass ratio of 1, but then remains relatively constant for mass ratios greater than this.

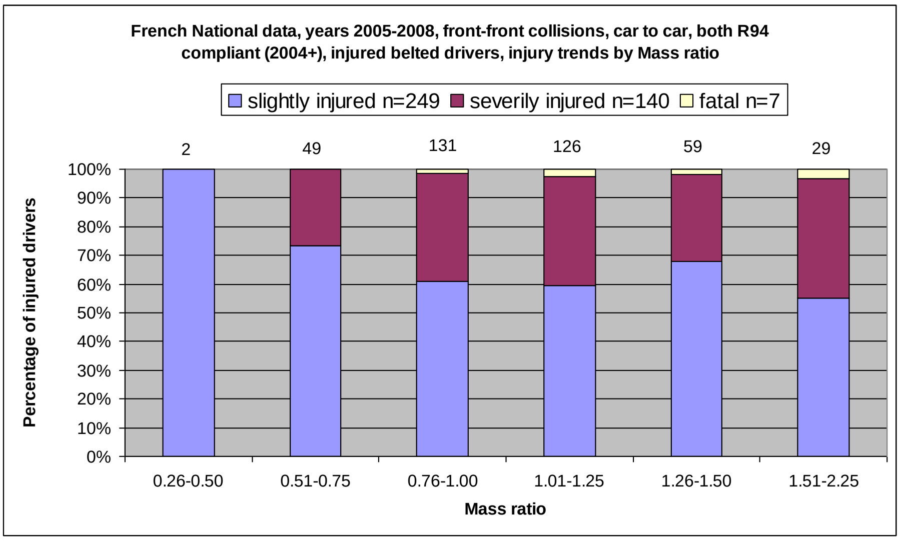


**Figure 7-14. Relationship between mass ratio and injury severity for France (from national data)**

#### *7.3.3.2 Cumulative mass ratio distribution*

Figure 7-15 shows the cumulative mass ratio for the cars in the French national data which were Regulation 94 compliant and involved in a frontal impact with another Regulation 94 compliant car.

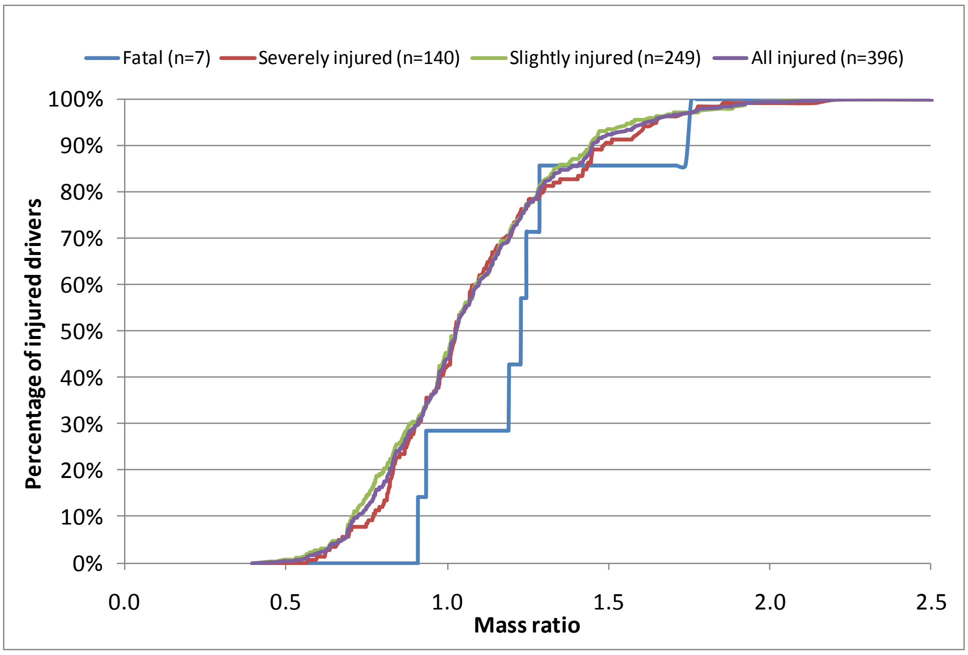


**Figure 7-15. Cumulative mass ratio for France – all masses of car (from national data)**

Figure 7-16 to Figure 7-20 show the cumulative mass ratio for the cars in the French national data, split by the mass of the subject vehicle. The mass groups used are: <1000kg, 1000-1200kg, 1201-1400kg, 1401-1600kg, and >1600kg. These figures show that, as the mass of the subject vehicle increases, the mass ratios needed to address a given percentage of the injured casualties reduces – as would be expected. If a new test is developed in which the mass ratio can be altered (e.g. a Mobile Deformable Barrier test), these data could be used to help choose a suitable mass ratio for testing vehicles in different mass categories to address a given percentage of the casualties.

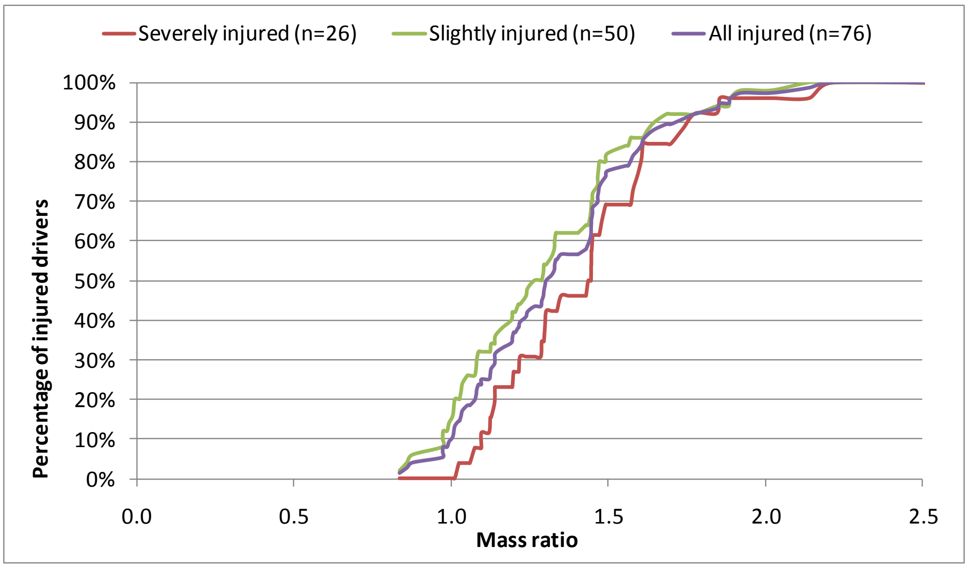


**Figure 7-16. Cumulative mass ratio for France – subject vehicle <1000kg (from national data)**

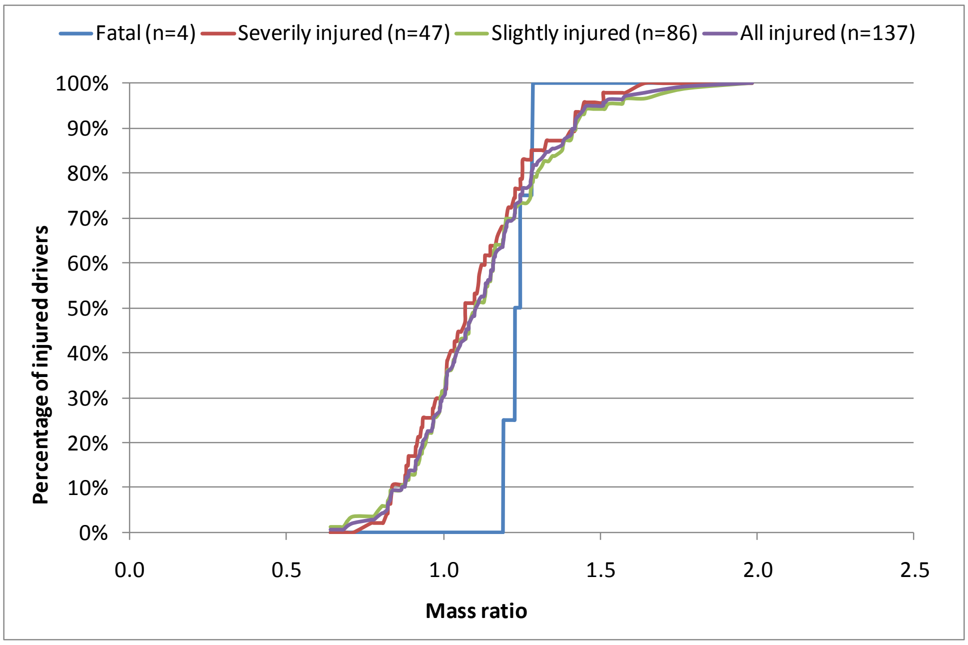


**Figure 7-17. Cumulative mass ratio for France – subject vehicle 1000-1200kg (from national data)**

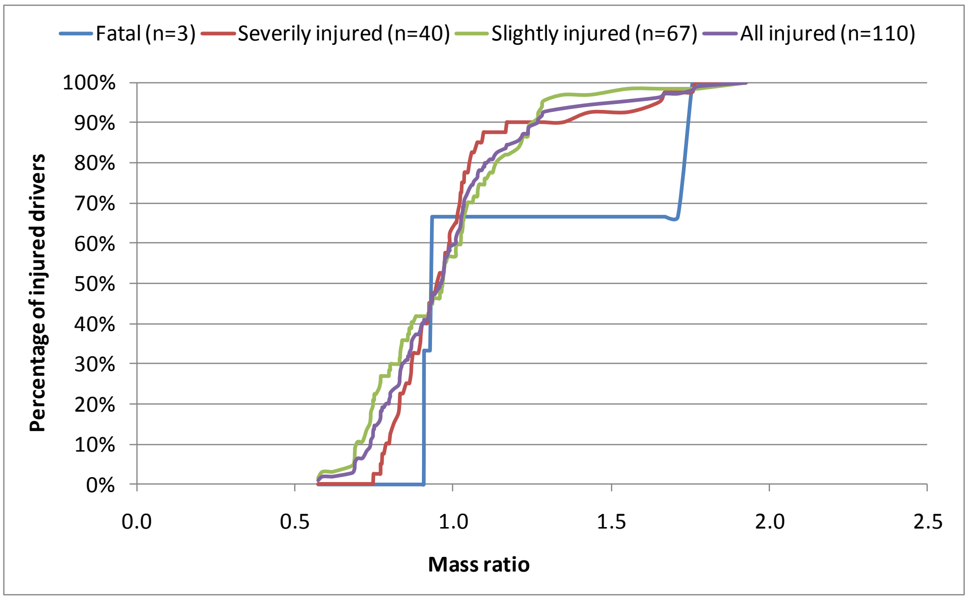


**Figure 7-18. Cumulative mass ratio for France – subject vehicle 1201-1400kg (from national data)**

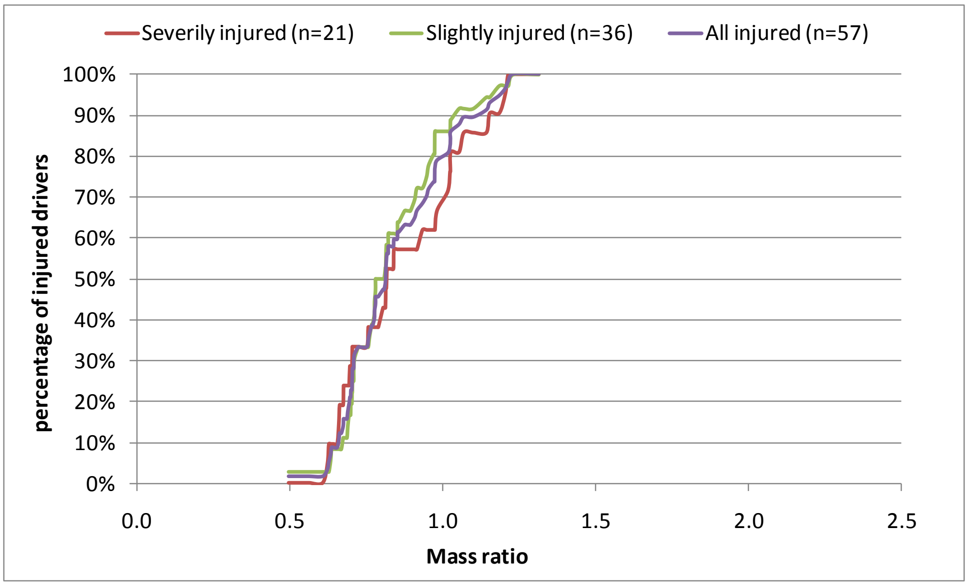


**Figure 7-19. Cumulative mass ratio for France – subject vehicle 1401-1600kg (from national data)**

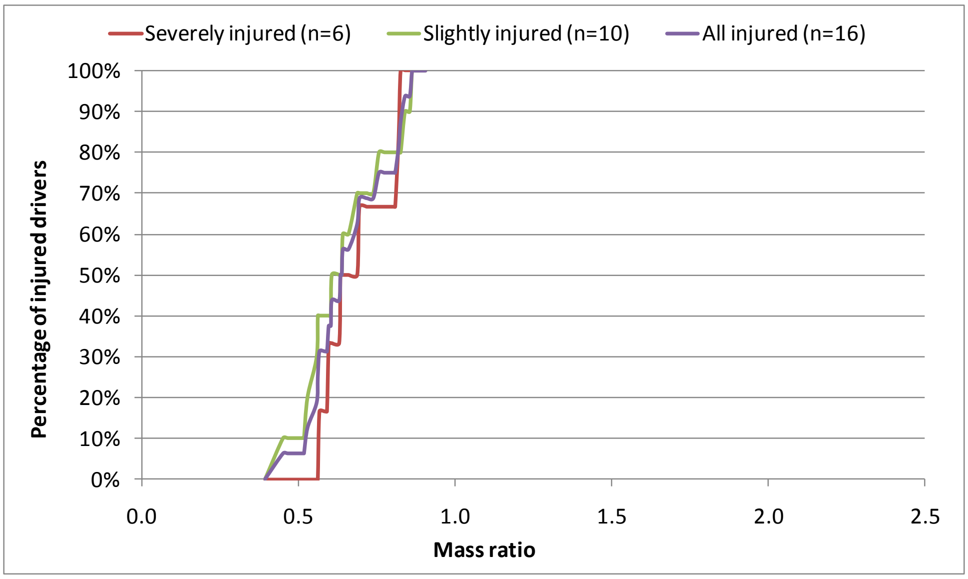


**Figure 7-20. Cumulative mass ratio for France – subject vehicle >1600kg (from national data)**

Figure 7-21 and Figure 7-22 show the cumulative mass ratio for occupants in the in-depth accident data from Great Britain and Germany respectively. These are smaller samples than the French national data, and so these figures cannot be split by the mass of the subject vehicle.

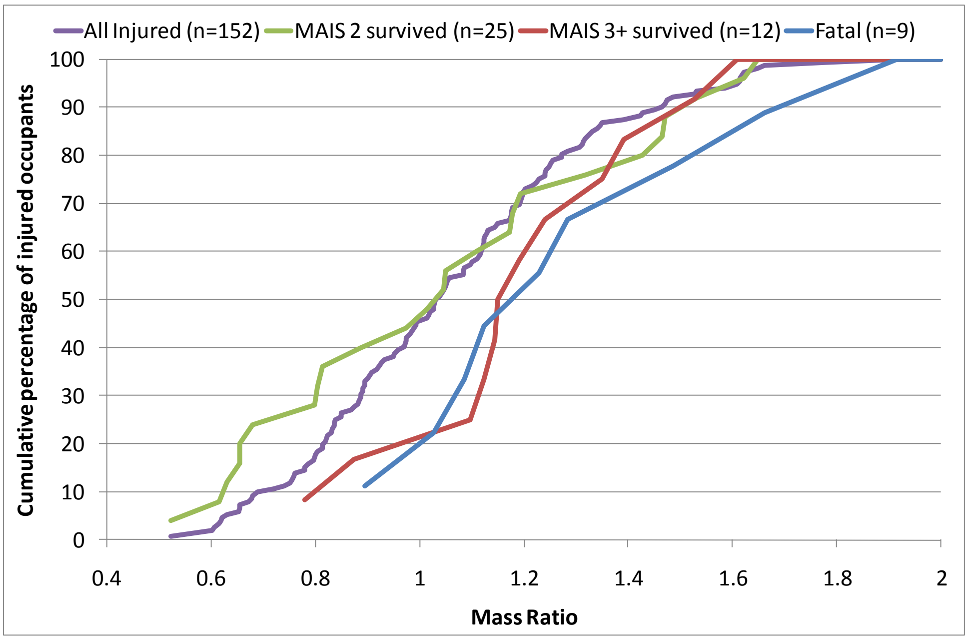


**Figure 7-21. Cumulative mass ratio distribution for Great Britain (from CCIS)**

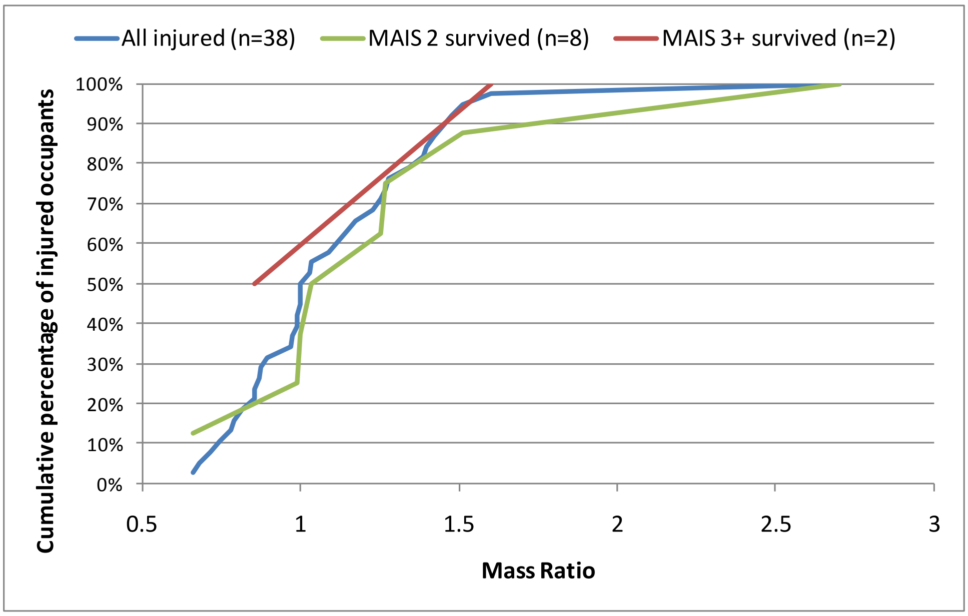


**Figure 7-22. Cumulative mass ratio distribution for Germany (from GIDAS)**

## 7.4 Summary of findings and regulatory implications

### *7.4.1 Aggressivity – partner protection*

Aggressivity was calculated as the proportion of driver fatalities in the impact partner to the number of crashes of the subject vehicle. This was calculated for different masses and vehicles types in the national data of Great Britain, France, and Germany. Three combinations of impacts were investigated: all vehicles vs all vehicles, R94 compliant vehicles vs all vehicles, and R94 compliant vehicles vs R94 compliant vehicles.

- Generally, as vehicle mass or size increases, aggressivity also increases. This relationship was seen for all three countries, and for all three combinations of vehicle age. This suggests that there is a compatibility problem – impacts with heavier vehicles cause more fatal and serious injuries. However, for the R94 vs R94 sample in Great Britain this trend was less clear.

- The aggressivity of R94 vehicles in impacts with other R94 vehicles is less than the aggressivity of R94 vs all vehicles. As the fleet becomes saturated with Regulation 94 compliant vehicles this suggests that casualty rates will reduce and the compatibility problem will be lessened. However, the results from Germany suggest that the aggressivity of larger vehicles is larger for R94 vs R94 vehicles compared to all vs all impacts. This would mean that the compatibility problem in a R94 compliant fleet would be worse than the compatibility problem before Regulation 94 was introduced.
- The national data in Great Britain was used to investigate the aggressivity of Light Goods Vehicles (LGVs) which are classified as $N_1$ vehicles. In front-front crashes involving two vehicles both registered in October 2003 or later, the aggressivity of $N_1$ vehicles was surprisingly low, comparable to the aggressivity of a medium size car. This suggests that Regulation 94 compliant cars can perform well in impacts with $N_1$ vehicles and there is not a particular compatibility problem in crashes between post 2003 $N_1$ vehicles and cars.

#### *7.4.2 Severity proportion – self protection*

The severity proportion was defined in two ways: either the proportion of all driver casualties who were killed or seriously injured, or the proportion of all drivers involved in accidents (including uninjured drivers) who were killed or seriously injured.

- The results from France show that there is little change of the severity ratio with the mass of the vehicle, in car-car or car-single vehicle accidents involving Regulation 94 compliant cars only. The results from Great Britain for Regulation 94 compliant cars hitting all ages of car also shows no relationship between severity proportion and mass. This suggests that there is not a large compatibility problem.
- However, the results from the German national data suggest that the severity ratio decreases as the vehicle mass increases, up until a mass of 1400 kg, suggesting that there is a compatibility problem for vehicles under this mass.
- When adjusting for age, gender, and location in Great Britain and Germany it is clear that there in a wide variation of severity proportions for different masses of car. This suggests that there are more important effects than mass, age, gender, and location that cannot be adjusted for using the national data. These may include the severity of the accident, seat belt use, etc.
- There are a number of limitations of using the severity proportion to ascertain the self protection of a group of vehicles. There are many confounding factors which have not been taken into account in this analysis which could be affecting the results, such as type of driver and impact severity. There are other types of analysis, such as paired analysis, which may be able to account for these differences.

#### *7.4.3 Mass ratio*

The mass ratio is calculated as the mass of the impact partner divided by the mass of the subject vehicle.

- The data from Great Britain and France suggest that increasing mass ratio (i.e. the subject vehicle has smaller mass than the impact partner) gives an increasing rate of fatal or severe injury.
- Cumulative mass ratios from the French national accident data show that as the mass of the subject vehicle increases, the mass ratios needed to address a given

percentage of the injured casualties reduces – as was expected. If a new test is developed in which the mass ratio can be altered (e.g. a Mobile Deformable Barrier test), these data could be used to help choose a suitable mass ratio for testing vehicles in different mass categories to address a given percentage of the casualties.

# 8 Conclusions

A comprehensive European accident study for frontal impact was performed to help prioritise frontal impact scenarios for casualty reduction and potential future changes to frontal impact legislation, namely Regulation 94, for both the short and longer term. This study involved analysis of European, UK, German and French national and detailed level databases and consisted of the following parts:

- Identification of the taxonomy of frontal impact accidents in Europe and quantification of associated target populations for potential changes to frontal impact legislation.
- Detailed case analysis to investigate how well the current Regulation 94 test represents real-world accidents and help identify any modifications which should be made to it.
- Analysis of car to other vehicle impacts to help understand the nature and magnitude of the compatibility problem in frontal impacts.

When appropriate as far as was possible only Regulation 94 compliant vehicles (or those with an equivalent safety level) were selected for the study to ensure that the results were representative of the performance of Regulation 94 compliant vehicles and hence appropriate for use to set priorities for an update of Regulation 94.

Throughout the analysis care was taken to ensure that the relationship between the accident data samples used to investigate specific factors, the whole database and the European picture was known, so that it was possible to scale back up to estimate what effect changing a particular factor may have on the European picture.

A summary of the main conclusions and the regulatory implications for each part of the analysis are given below. More details can be found in the 'Summary of findings and regulatory implications' at the end of the previous sections.

## 8.1 Frontal impact taxonomy and target populations

**Overall**

- Road accident fatalities in the EU27 and in particular car occupant fatalities have reduced by approximately 30% in the period 1998 to 2007 following the introduction of measures to improve car occupant safety such as the frontal and side impact directives / regulations and Euro NCAP. However, based on accident data from GB, France and Germany car occupant fatalities still account for about half of all road accident fatalities (EU27 in 2007: 42,854) and hence remain a substantial problem.
    - Fatality reduction in Germany and France is substantially higher than in Great Britain (26% in Great Britain, 50% in Germany, 62% in France). However Great Britain has the lowest number of fatalities per head of population.
- National data from Great Britain, Germany, and France indicate that car occupant fatalities form approximately half of all road accident fatalities. Car frontal impacts account for between 59-63% of car fatalities (731 in Great Britain, 1,398 in France). This illustrates the substantial size of the target population for potential changes to Regulation 94 (EU27 in 2007: 42,854*0.5*0.6 = 12,856).
- The adjustments to the 2008 frontal impact casualty figures, to estimate the number of casualties assuming all cars are compliant with Regulation 94, were as follows:
    - Great Britain: 98% of fatalities, 90% of serious casualties
    - France: 80% of fatalities, 89% of serious casualties

  This suggests that, although the number of fatalities and serious injuries may be reduced once the entire fleet is Regulation 94 compliant, there will still be a significant number of deaths and serious injuries in frontal impacts.

- One of the most important findings from this analysis was the large effect on the size of the target populations of excluding casualties who would not likely benefit from potential changes to improve Regulation 94, namely those who were unbelted, were seated in front of an unbelted occupant or were involved in an accident in which the vehicle rolled over. Once these occupants were excluded, the size of the target populations expressed as a percentage of all car occupant casualties in frontal impacts were as follows:
  - Fatalities – 52% in Great Britain, 64% in Germany, 80% in France
  - MAIS 3+ survived – 61% in Great Britain, 78% in Germany
  - MAIS 2 survived – 74% in Great Britain, 78% in Germany

  It is seen that the target population for fatalities for France was high compared to Great Britain and Germany. This may be because for France, national data rather than detailed accident data was used to determine seatbelt use and it is likely that seat belt use is over-estimated in this database.

  The regulatory implication is that measures to improve protection offered for those casualties excluded from the target population, in particular to increase seatbelt wearing rates, should be considered strongly because they could offer substantial benefit on their own merits and maximise the benefit of other potential changes to Regulation 94.
- An investigation of the effect of vehicle age on its safety performance was performed by comparing the severity proportion of casualties in different aged vehicles using national data from Great Britain, Germany and France. It found that for all frontal impacts and the subset of frontal car-to-car impacts when the age of the partner car is not taken into account the severity proportion for fatalities and KSI is significantly lower for new cars ($1^{st}$ Oct 2003+) compared to old cars (1994-1998). This indicates that newer cars are 'safer' than older cars. However, when the age of the partner was vehicle taken into account, there were indications of some increases in severity proportion for new-new ($1^{st}$ Oct 2003+) cars compared to old-old cars (1994-1998). This increase was seen in Germany for fatalities and in Great Britain for KSI. These increases in severity proportion are a possible indication that safety in car-to-car impacts has not improved; however there are many confounding factors which have not been taken into account in this analysis which could be affecting the results, such as type of driver, mass of vehicle, type of vehicle, driver age and gender, and impact severity.

Note that target population percentages quoted in sections below are of all car occupant frontal impact casualties for that country and exclude occupants who were unbelted, had an unbelted occupant seated behind them or were involved in a rollover.

**Impact configuration**

- Impact partner
  - For GB, Germany and France the sizes of the target populations in the different impact categories are shown in Table 8-1. This shows that:
    - Impacts with cars or LGVs are generally the largest target population group in all three countries and at all injury levels. This indicates that car-to-car / car-to-LGV compatibility should be an important consideration for potential changes to Regulation 94.
    - The size of the target population group for narrow objects (< 41 cm wide, e.g. poles, small diameter trees) is small; 5-6% of casualties, depending on severity for GB and 10-16% of casualties for Germany. This gives an indication that the benefit of the introduction of a frontal pole test into Regulation 94 would likely be low and hence should not be considered as a high priority.

**Table 8-1. Proportion of all car occupant frontal impact casualties in target population groups for different impact configurations**

| Impact with | Fatal | | | MAIS 3+ survived | | MAIS 2 survived | |
|---|---|---|---|---|---|---|---|
| | GB | Germany | France | GB | Germany | GB | Germany |
| Car/LGV | 30% | 22% | 26% | 37% | 33% | 45% | 49% |
| HGV/bus | 10% | 11% | 18% | 4% | 13% | 4% | 9% |
| Wide object | 6% | 18% | 36% | 7% | 16% | 12% | 11% |
| Narrow object | 5% | 13% | | 6% | 16% | 6% | 10% |

Note: Conclusions in remainder of section below are based on GB and German data only.

- Overlap
  - For GB and Germany analysis showed that impacts involving direct loading to only one longitudinal (like the current offset test) account for a larger proportion of impacts than other impact types, the next most frequent being impacts directly loading both longitudinals, followed by low overlap impacts with no direct loading to the longitudinals. The target population of impacts loading both longitudinals is 18-29% of all frontal impact casualties, depending on severity. High overlap crashes (> 90% overlap) are a similar proportion, 15-27% of frontal impact casualties in Great Britain and Germany. These are the potential sizes of the populations which could benefit if a full width test was introduced. For Great Britain the target population for low overlap crashes with no direct loading to the longitudinals is 5-12% depending on severity. This indicates that the introduction of a full width overlap test into Regulation 94 should be an important consideration for potential changes to Regulation 94.
- Severity
  - Increasing the Equivalent Energy Speed (EES) from 50 kph to 56 kph (which approximately relate to the severity of Regulation and EuroNCAP tests respectively) increases the target population by 3-5% of all frontal impact casualties in Great Britain depending on severity, although this increase is smaller in Germany (about 1%). However, it should be noted that for GB over half of fatalities are in impacts with a higher severity than both these speeds. There are also a large proportion of fatalities at relatively low severities, the majority of which are elderly occupants. This indicates that the potential benefit to Regulation 94 to increase the test severity to that of the Euro NCAP test may not be that high.
- Covered by Regulation 94 ODB test
  - The target population of casualties in impacts with a configuration that are covered by the current Regulation 94 test varies from 7% for fatalities to 18% for MAIS 2 surviving casualties (16% in Germany). This indicates that there could be large potential benefit if the proportion of impacts that are covered by the regulation could be increased by measures such as the additional of a full width test.

**Population injured**

- Age
  - In Great Britain and France, the national data showed that elderly occupants (aged 66 or over) make up 20% of car fatalities in frontal impacts. This shows

that elderly occupants form a large proportion of fatalities and because demographically the proportion of older people in Europe is growing, it is suggested that future potential changes to Regulation 94 should consider older occupants. However, it should be noted that the largest proportion of fatalities are aged 12-25 years, which account for 34% of fatalities in Great Britain and 29% in France.

  - Analysis of the detailed accident data showed that a large proportion of the target population were elderly occupants aged 66 or older, accounting for 12-25% of all frontal impact casualties in Great Britain depending on severity. Even though elderly occupants are over-represented in the GB CCIS data sample, the German analysis also showed that elderly occupants could make up 15% of the target population of MAIS 2 surviving occupants – the same proportion as for MAIS 2 surviving occupants in Great Britain.

- Seating position
  - Drivers are a much larger proportion of the target population than front seat passengers. In car-car/LGV impacts alone in Great Britain, the target population of driver casualties is 23-34% of all frontal impact casualties depending on severity, compared to 7-11% for front seat passengers. The proportion of rear seat passengers in the target population is much smaller than both, partially because of the low seat belt wearing rates in the rear.
    - The age and gender of occupants in different seating positions is substantially different. The majority of front seat passengers are female, and a large proportion of these are elderly. Female front seat passengers in car-car/LGV impacts account for 7-9% of frontal impact casualties. A large proportion of rear seat passengers are children or young adults. A suitable dummy to represent the most frequently injured casualty in the front passenger seat would therefore represent a female or elderly female, while a suitable dummy in the rear would represent a child or young adult.

**Frequency and severity of injury**

- In Great Britain, for all injury severities, injuries to the thorax, arms, and legs are the most frequent. For fatalities, injuries to the abdomen are also frequent. The target population of casualties with MAIS 2+ injuries to the thorax is 23-42% of casualties depending on severity; arms are 25-32% of casualties; legs are 17-32% of casualties; and abdomen are 30% of fatalities. The indicates that the dummy used in any regulatory test should be capable of measuring injury criteria in all of these regions, and better protection should be provided for these body regions.
    - The injury distribution in Germany is slightly different - for MAIS 2 surviving occupants more head injuries and fewer leg injuries are seen compared to Great Britain. The target population of MAIS 2 casualties with head injuries in Germany is 21%, compared to 6% in Great Britain, suggesting that measurement of head injury is also important.
    - For Great Britain, for MAIS 2 injured casualties the frequency of AIS 2 thorax injury is substantially higher for older casualties (46 and over) compared to younger casualties (45 and under).
- For car drivers in car-car/LGV impacts in the GB data, the injury mechanisms are related to both the injury severity and the individual body regions.
    - For MAIS 2 surviving drivers, injuries to the thorax are generally related to the restraint system, injuries to the legs are related to contact with non-intruding structures, and injuries to the arms are related to a combination of both these causes (the restraint induced injuries are probably to the

clavice and shoulder area, and the contact injuries are likely to be to other regions of the arms).

  - As the injury severity becomes more severe, a larger proportion of injuries are related to contact with intruding structures. For fatalities, the majority of injuries to all body regions (with the exception of the abdomen) are related to contact with intruding structures. For MAIS 3+ surviving occupants, the majority of thorax injuries are still related to the restraint system, but injuries to the legs are distributed between contact with intruding and non-intruding structures.

- No difference was found in the injury distribution of male and female drivers in impacts with cars or Light Goods Vehicles (LGVs) in Great Britain. The injury distribution of different age drivers showed that the proportion of MAIS 2 casualties receiving thorax injuries is greatest for elderly casualties.

**Rear seat occupants**

- At present the rear seat occupant position is not tested in Regulation 94. Based on national data from Great Britain and France, the proportion of car occupant fatalities seated in the rear is small (9-10%) which indicates that the target population for a potential change to the Regulation is also small.
- GB data shows that the seat-belt usage rate for rear seat occupants is substantially lower than for front seat occupants.
- Partially because of their low seat belt use, the number of rear seat passenger casualties in the target population is relatively small – 1% of fatal casualties, 6% of MAIS 3+ surviving casualties, and 7% of MAIS 2 surviving casualties. However, their characteristics are different to those of drivers and front seat passengers.
  - A large proportion of rear seat passengers are children or young adults of both genders.
  - A large proportion of MAIS 3+ surviving rear seat passengers have AIS 2+ abdomen injuries, although the target population of casualties with these injuries is approximately 1% of all MAIS 3+ surviving frontal impact casualties.

**$N_1$ vehicles (and 2.5 t < $M_1$ < 3.5 t)**

- It was not possible to identify clearly vehicles between 2.5 t and 3.5 t in any of the accident databases used and therefore no analysis could be performed to investigate their characteristics.
- The number of $N_1$ (LGV) fatalities (<2% of all road fatalities) is low in Great Britain, France and Germany compared with $M_1$ casualties (~50% of road fatalities). This gives an approximate size for the target population of casualties which could be affected by extending the scope of Regulation 94 to include $N_1$ vehicles. However, a small target population alone does not indicate that such a scope change should not be considered further. This is because the number of $N_1$ vehicles compared to cars on European roads is also low which indicates that the total cost to modify them to be compliant with Regulation 94 may also be low, which in turn indicates that the cost to benefit ratio for this potential change to Regulation 94 could be better than for other potential changes for cars.
- From analysis of the GB Heavy Vehicles Crash Injury Study (HVCIS) fatals database it was seen that the seat belt usage rate for these fatalities in $N_1$ vehicles was about 35% - much lower than for fatalities in cars, where the seat belt wearing rate for fatalities was above 65%. The analysis also showed that the majority of these $N_1$

vehicle fatalities were male (over 95%), and there were fewer elderly fatalities than were seen in cars.

It should be noted that Table 5-2 to Table 5-5 show a useful summary of the target population sizes for impact configuration and casualty injury characteristics. The tables are presented by injury severity (Fatal, MAIS 3+ survived and MAIS 2+ survived) and show the target populations as a proportion of all car occupant casualties in frontal impacts that had that characteristic.

## 8.2 Detailed case analysis

- 48 fatalities in Regulation 94 compliant cars were selected from the GB CCIS database and investigated in detail to help determine why people are still dying in frontal crashes despite seat belt use, airbags and the crashworthy structures of modern vehicles. The main reasons determined in order of importance were:
    - High severity of the crash
    - Elevated age of the occupant
    - Underride and limited horizontal structural engagement with partner vehicle
- 25 occupants of Regulation 94 compliant cars involved in impacts similar to the Regulation 94 test were identified in the GB CCIS database. Based the Euro NCAP test results, an assessment of the structural performance of the car and the occupant injuries in each accident case was made. If the assessment was "worse than expected", reasons why were determined.
    - The injury outcome was only assessed as "worse than expected" when the car's structural performance was also assessed as "worse than expected". In the 5 cases where this occurred the reasons determined for the "worse than expected" injury outcome were related to the large amount of intrusion into the passenger compartment, which was caused by poor structural performance of the car, which in turn was related to issues of poor compatibility and structural interaction. This highlights the importance of considering potential changes to Regulation 94 to improve a vehicle's compatibility and structural interaction potential.

## 8.3 Compatibility

- To understand the nature and magnitude of the compatibility problem in frontal impacts a three part analysis was performed using accident data from Great Britain, Germany and France.
    - The first part focused on partner protection and determined an aggressivity metric for different vehicle masses and sizes. For all 3 countries it found that as vehicle mass or size increases, aggressivity also increases, although this trend was less clear for the British data. This suggests there is a compatibility problem.
    - The second part focused on self protection and determined a severity proportion for different masses. Overall, the results from this analysis were unclear. However, it should be noted that there were many confounding factors which were not taken into account in this analysis which could be affecting the results, such as type of driver and impact severity. Hence, if it is decided to take this work forward it is recommended that a different approach is tried in which these confounding factors could be removed, for example a matched pair type of analysis.
    - The third part investigated the relationship between mass ratio of the vehicles involved in the impact and injury severity of the drivers in the

vehicles. Data from Great Britain and France suggest a trend that increasing mass ratio (i.e. the subject vehicle has smaller mass than the impact partner) gives an increasing rate of fatal or severe injury. Cumulative mass ratios from the French national accident data show that as the mass of the subject vehicle increases, the mass ratios needed to address a given percentage of the injured casualties reduces – as was expected. If a new test is developed in which the mass ratio can be altered (e.g. a Mobile Deformable Barrier test), these data could be used to help choose a suitable mass ratio for testing vehicles in different mass categories to address a given percentage of the casualties.

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The work described in this report was carried out in the Crash Analysis group and the Vehicle Safety group of the Transport Research Laboratory. The authors are grateful to Mervyn Edwards who carried out the technical review and auditing of this report. The authors are also very grateful to Claus Pastor at BASt who provided the information for Germany, Cyril Chauvel and Gerard Faverjon at LAB who provided the information for France, and Gavin Buckle, Maureen Keigan, and Brian Lawton at TRL who provided the information from CARE and STATS19.

This report uses accident data from the United Kingdom Co-operative Crash Injury Study (CCIS) collected during the period 1998-2009.

CCIS was managed by TRL on behalf of the United Kingdom Department for Transport (DfT) who funded the project along with Autoliv, Ford Motor Company, Nissan Motor Company, Toyota Motor Europe, 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 of the DfT

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

This research uses accident data from the United Kingdom Heavy Vehicle Crash Injury Study (HVCIS), which is funded by the Department for Transport. The HVCIS database is managed by TRL on behalf of the Department for Transport.


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# Appendix A Representativeness of CCIS

Identifying the size of different target populations for regulatory changes has been performed by taking results from the in-depth database, and scaling these to represent the number of casualties nationally. When calculating the size of the target populations, the scaling took into account differences in injury severity, seating position, and impact type.

The differences in the severity distribution in the in-depth accident data from Great Britain (CCIS) and the national accident data (STATS19) are caused by the sampling procedure for CCIS, which favours fatal and serious accidents. The CCIS sampling procedure also favours new cars – however, because only Regulation 94 compliant vehicles were selected in CCIS and STATS19 this should not cause differences in the characteristics of the two samples.

Figure A - 1 compares the distribution of impact type for the cars in STATS19 and CCIS. There are some differences – for fatally injured occupants, there is a higher proportion of impacts with HGVs and buses and a lower proportion of impacts with narrow objects in CCIS than in STATS19. The size of the target populations have been adjusted to take these differences into account, as impact type was used to scale the results. However, the results from the case analysis in section 6 have not been scaled, so these cases are likely to include a higher proportion of HGV/bus impacts and a lower proportion of narrow object impacts than seen in the national accident population.

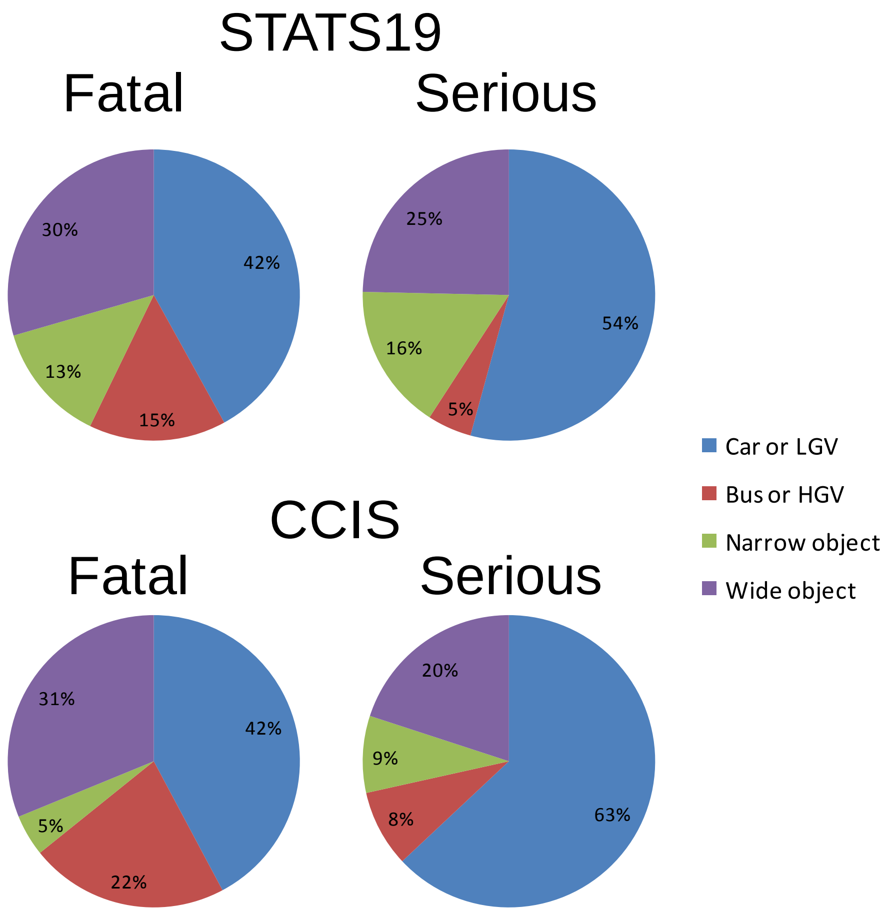



**Figure A - 1. Distribution of impact type for Regulation 94 compliant vehicles in STATS19 and CCIS**

Figure A - 2 shows the distribution of occupant age for the casualties in CCIS and STATS19. There are some differences between the two distributions – a greater proportion of the occupants in CCIS are elderly (aged 66 or older), and a smaller proportion are aged 12-25 years. The occupant age has not been used in the scaling of results to calculate the target populations, so these differences should be taken into account when looking at these results.

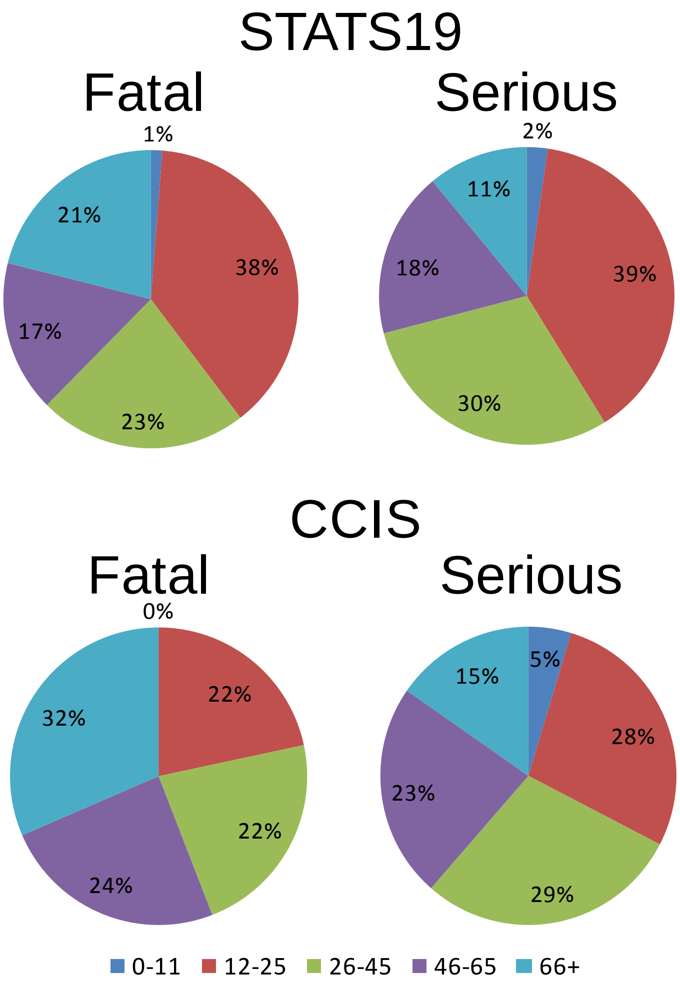



**Figure A - 2. Distribution of casualty age for Regulation 94 compliant vehicles in STATS19 and CCIS**

# Appendix B Results of in-depth accident data analysis

This section includes the results of the in-depth analysis that was performed using the CCIS database for Great Britain. This does not include the results for drivers in car-car/LGV impacts (which are shown in section 5.3.2.1 of the main body of the report) or the results for drivers and front seat passengers in car-LGV impacts in Germany (which are shown in section 5.3.2.2).

Only the figures with a sample size large enough to give meaningful results are included here.

## B.1 Front seat passengers in car-car/LGV impacts in Great Britain

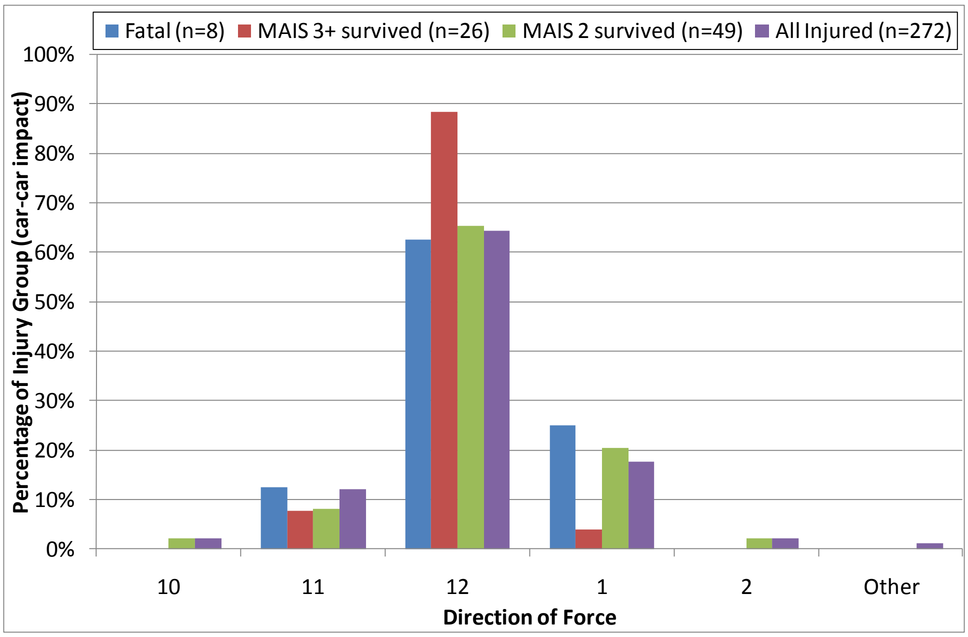



**Figure B - 1. Principle direction of force for front seat passengers in car-car/LGV impacts in Great Britain**

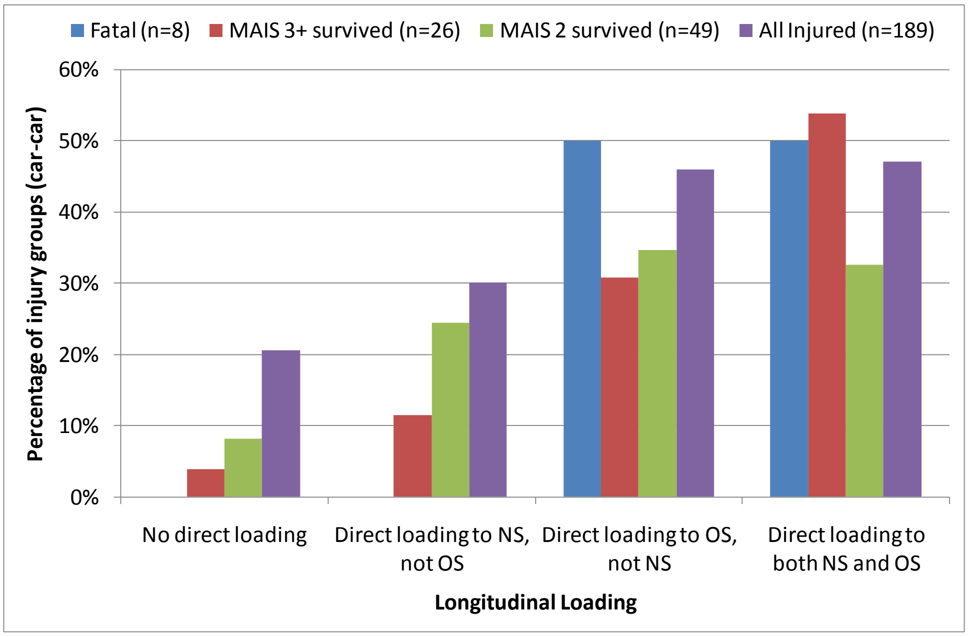



**Figure B - 2. Longitudinal loading for front seat passengers in car-car/LGV impacts in Great Britain**

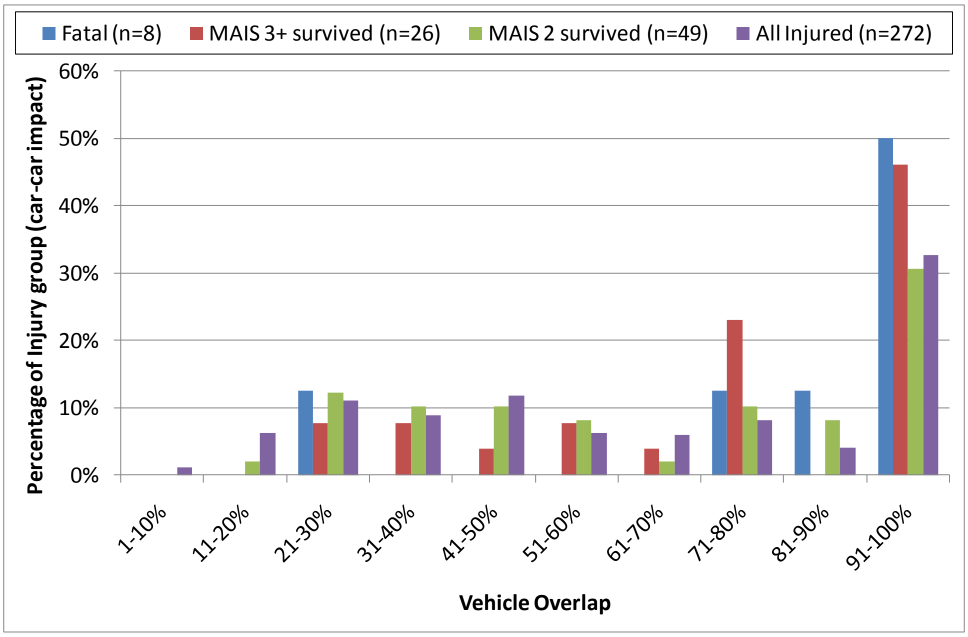



**Figure B - 3. Overlap for front seat passengers in car-car/LGV impacts in Great Britain**

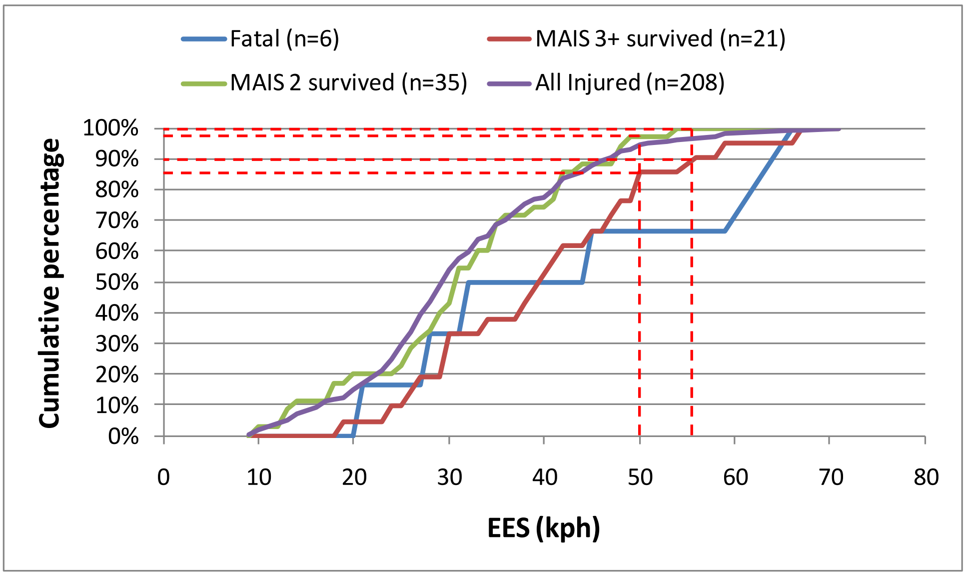



**Figure B - 4. Cumulative EES for front seat passengers in car-car/LGV impacts in Great Britain**

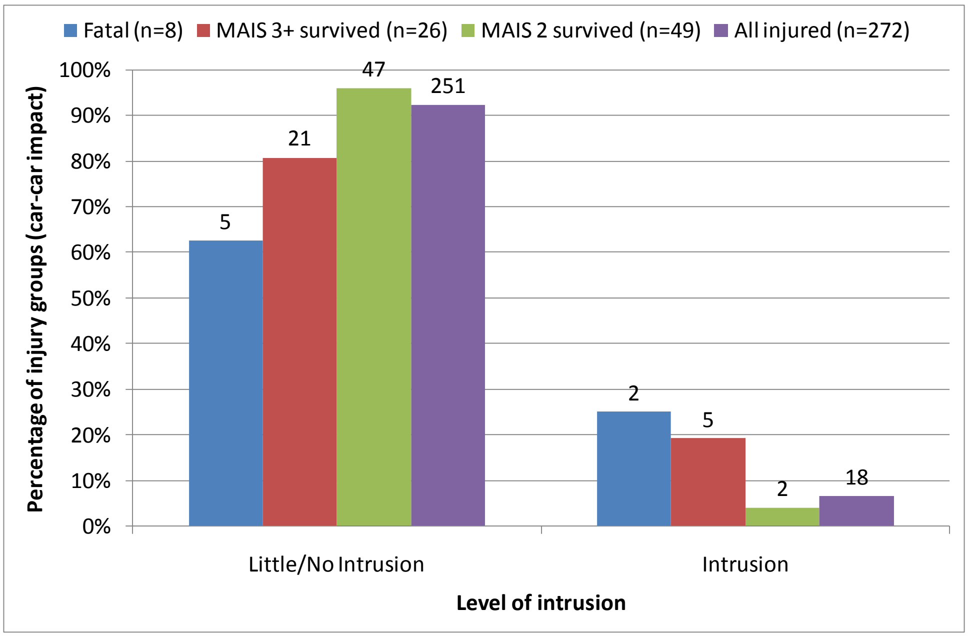



**Figure B - 5. Intrusion for front seat passengers in car-car/LGV impacts in Great Britain**

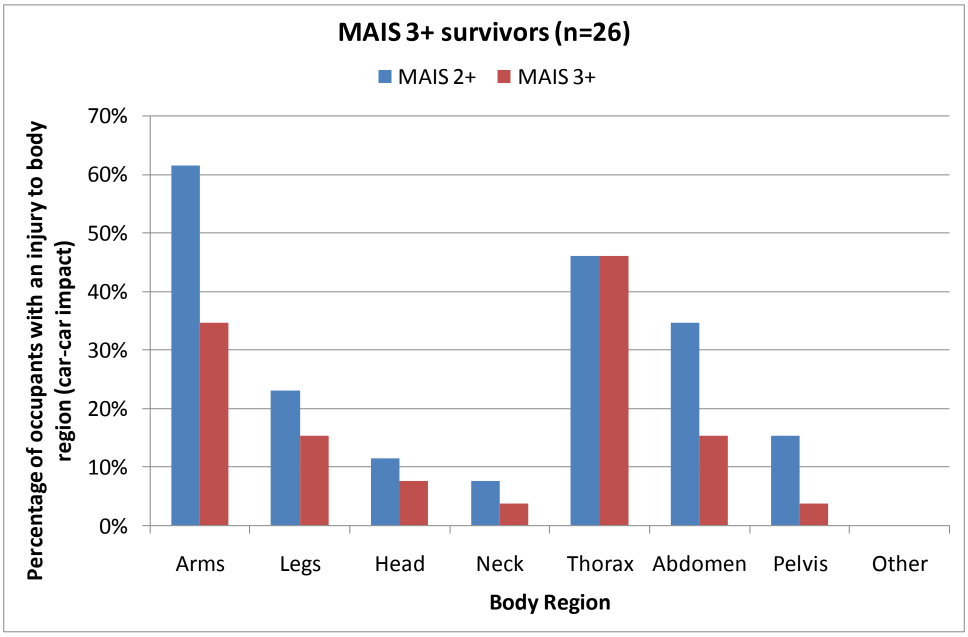



**Figure B - 6. Distribution of injuries for MAIS 3+ surviving front seat passengers in car-car/LGV impacts in Great Britain**

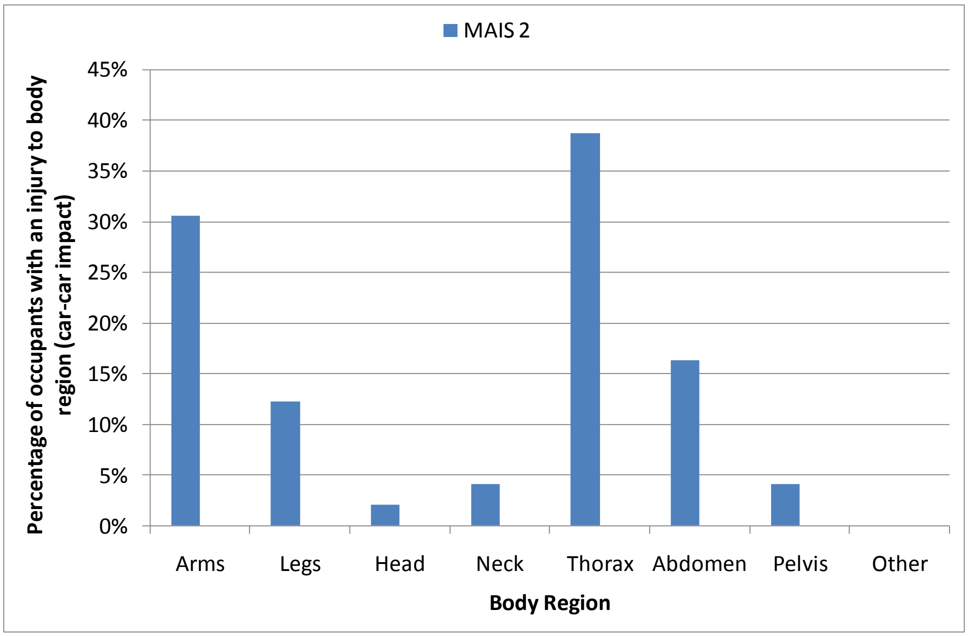



**Figure B - 7. Distribution of injuries for MAIS 2 surviving front seat passengers in car-car/LGV impacts in Great Britain**

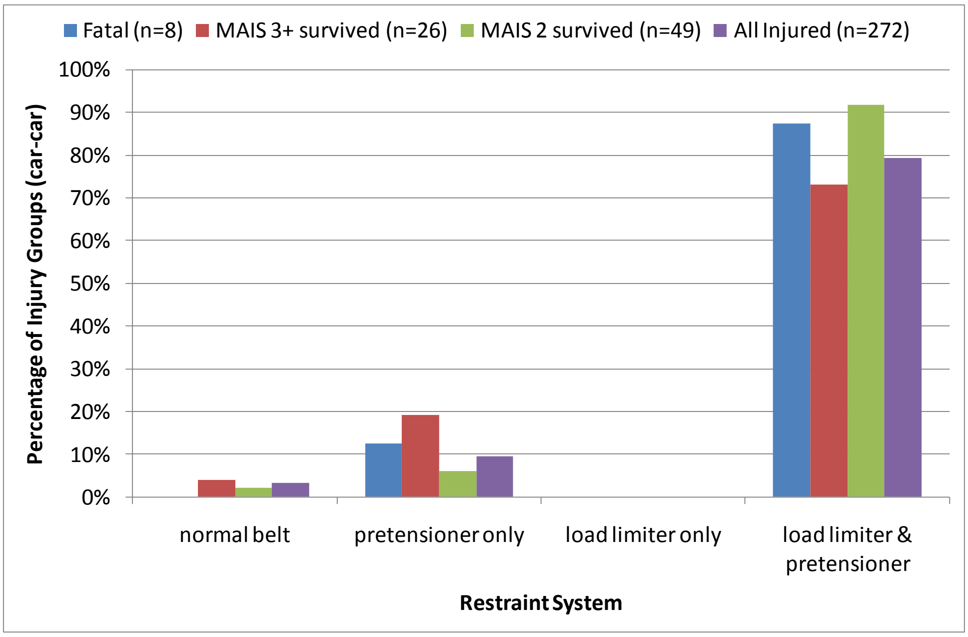



**Figure B - 8. Restraint system fitted for front seat passengers in car-car/LGV impacts in Great Britain**

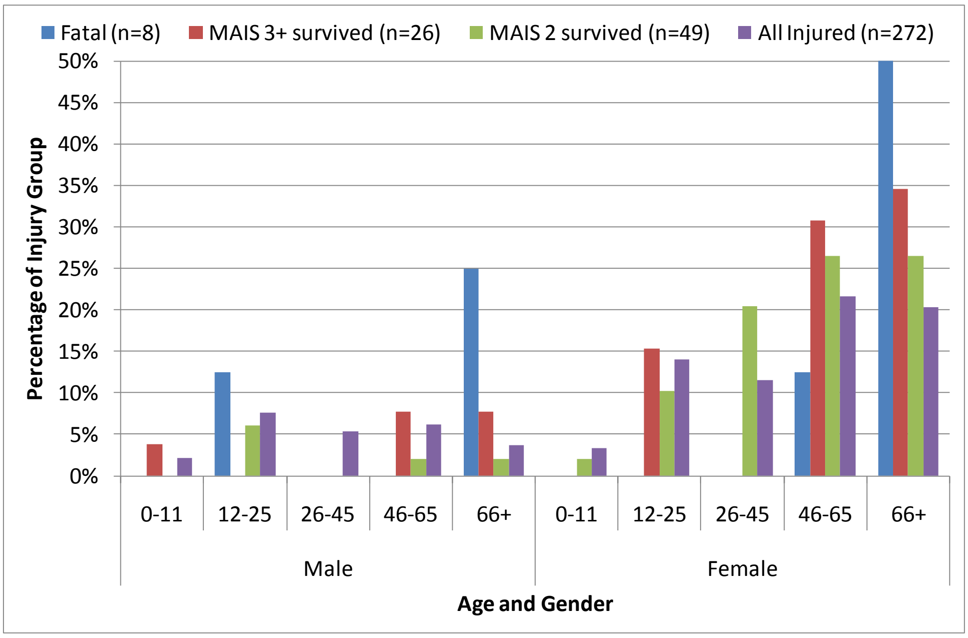



**Figure B - 9. Age and gender of front seat passengers in car-car/LGV impacts in Great Britain**

## B.2 Rear seat passengers in car impacts in Great Britain

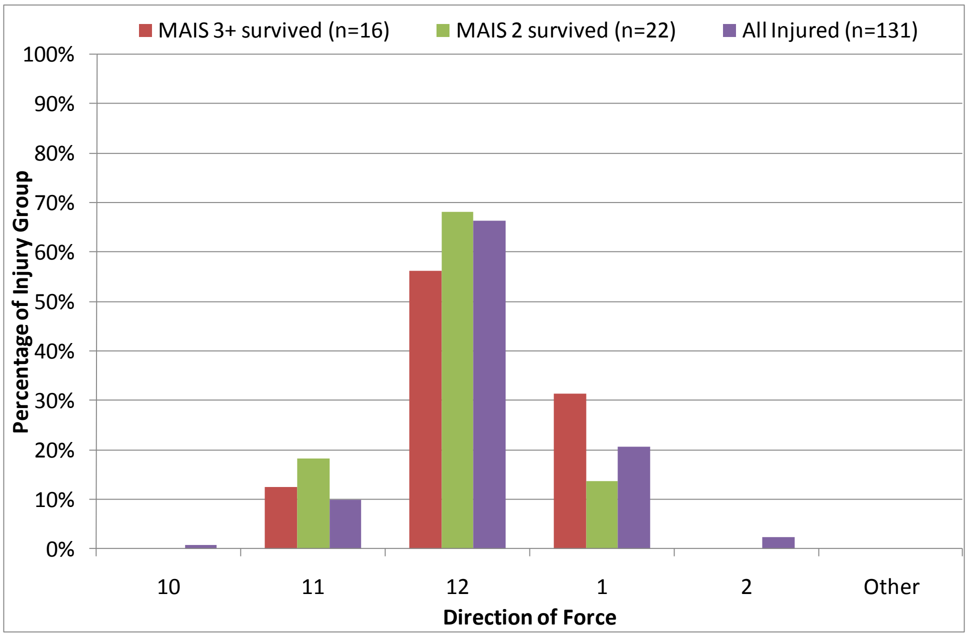



**Figure B - 10. Principle direction of force for rear seat passengers in car impacts in Great Britain**

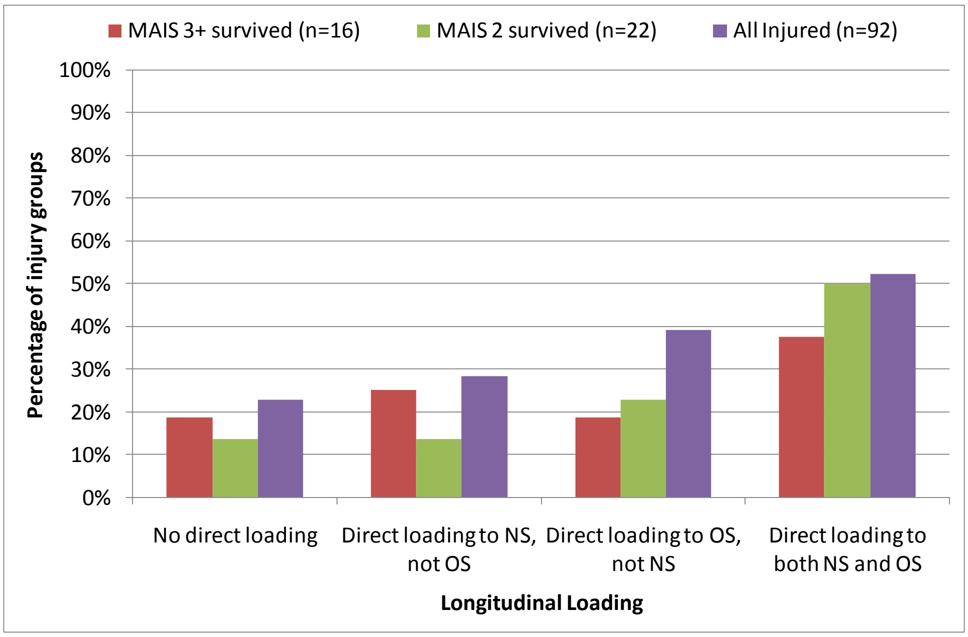



**Figure B - 11. Longitudinal loading for rear seat passengers in car impacts in Great Britain**

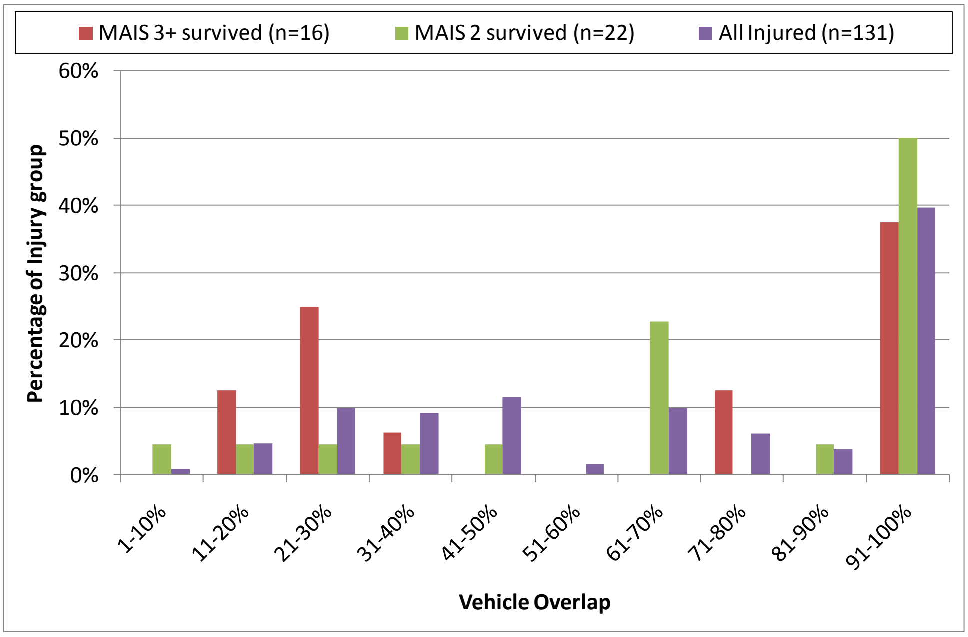



**Figure B - 12. Overlap for rear seat passengers in car impacts in Great Britain**

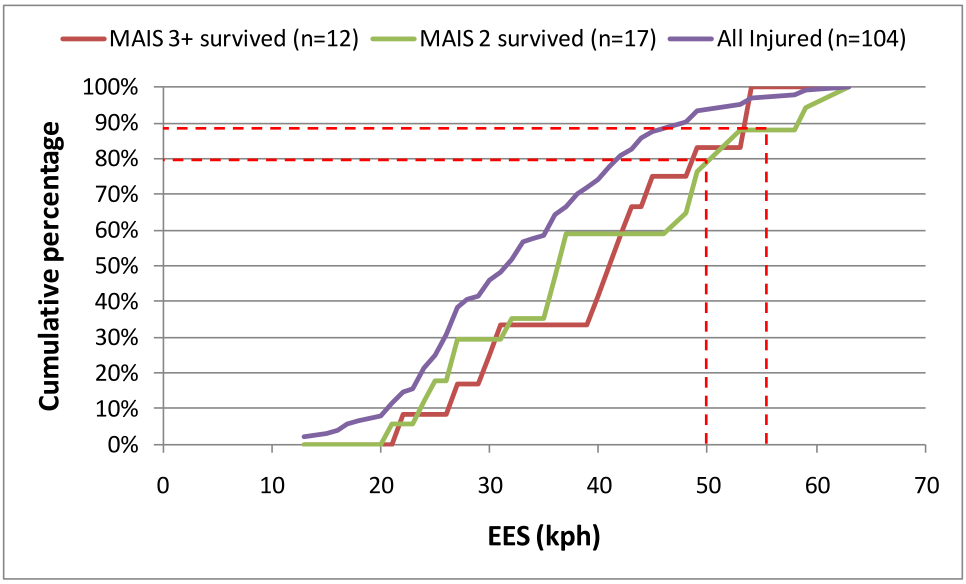



**Figure B - 13. Cumulative EES for rear seat passengers in car impacts in Great Britain**

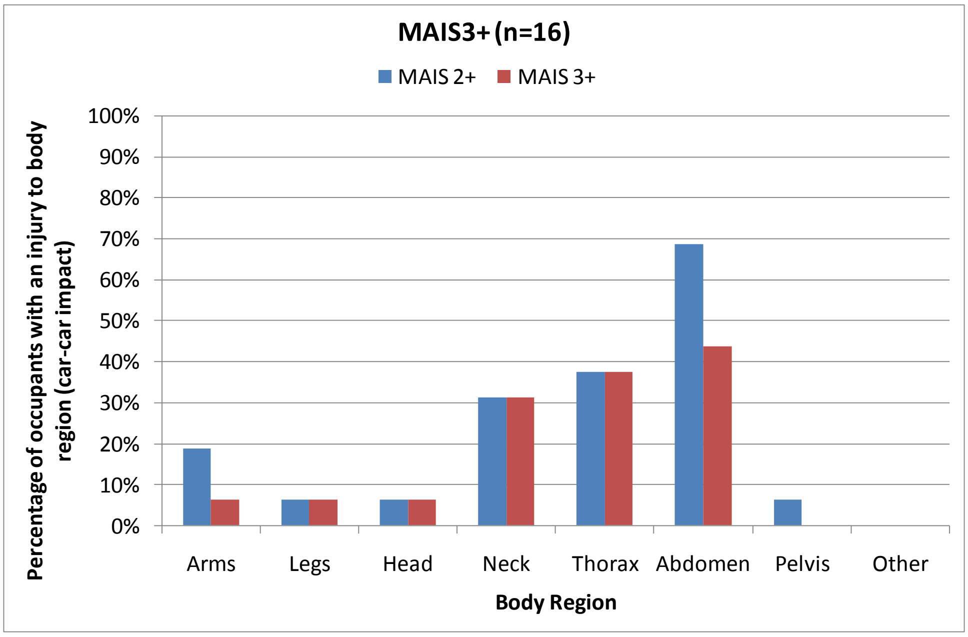



**Figure B - 14. Injury distribution of MAIS 3+ surviving rear seat passengers in car impacts in Great Britain**

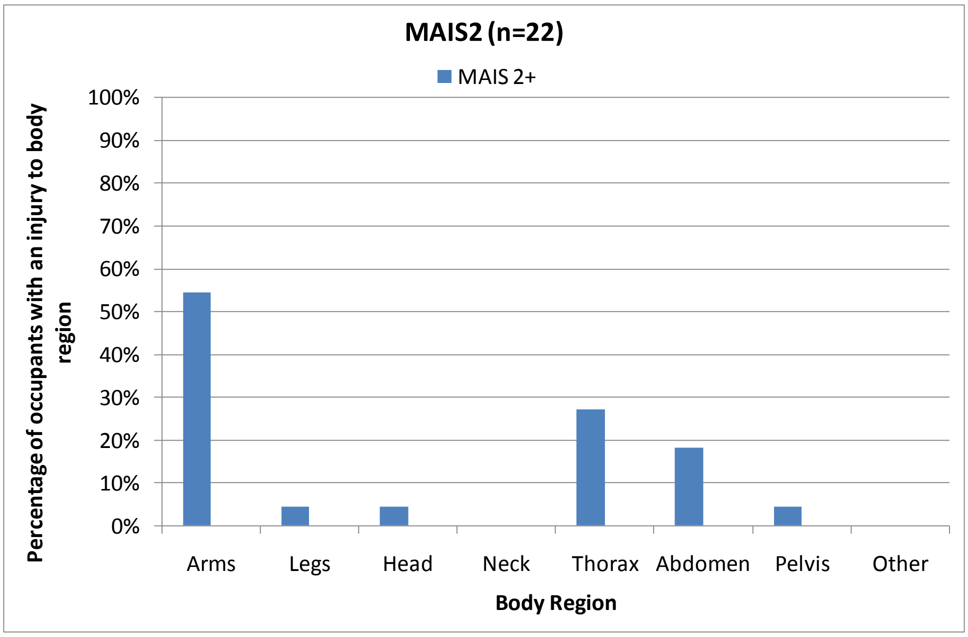



**Figure B - 15. Injury distribution of MAIS 2 surviving rear seat passengers in car impacts in Great Britain**

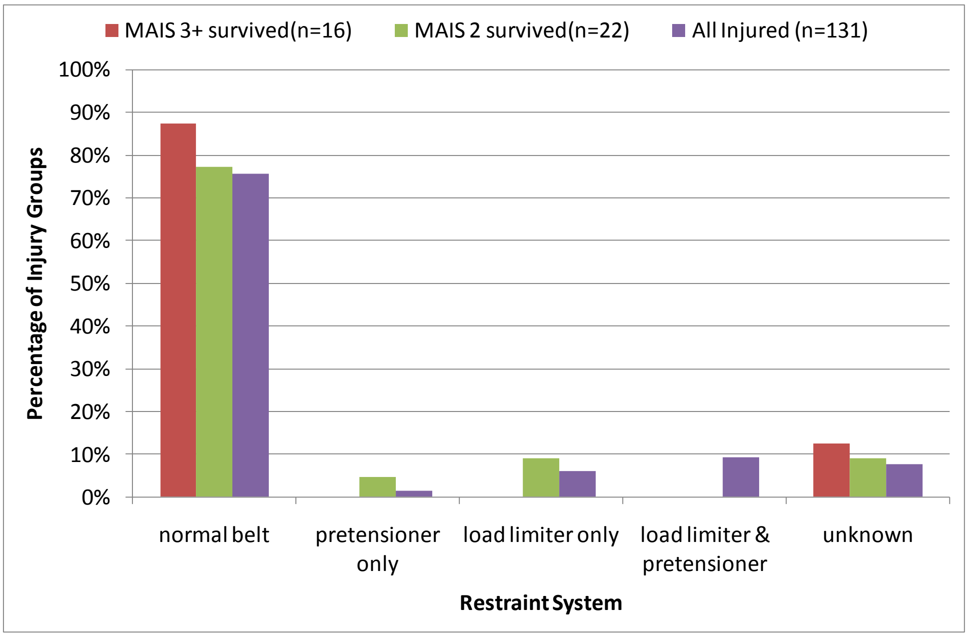



**Figure B - 16. Restraint system fitted for rear seat passengers in car impacts in Great Britain**

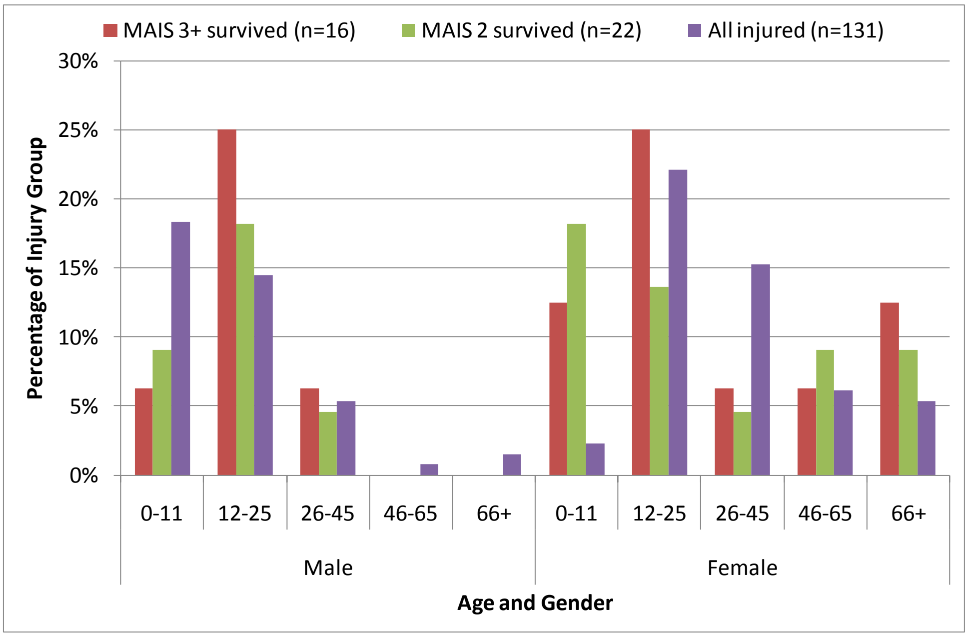



**Figure B - 17. Age and gender of rear seat passengers in car impacts in Great Britain**

## B.3 Drivers and front seat passengers in car-HGV/bus impacts in Great Britain

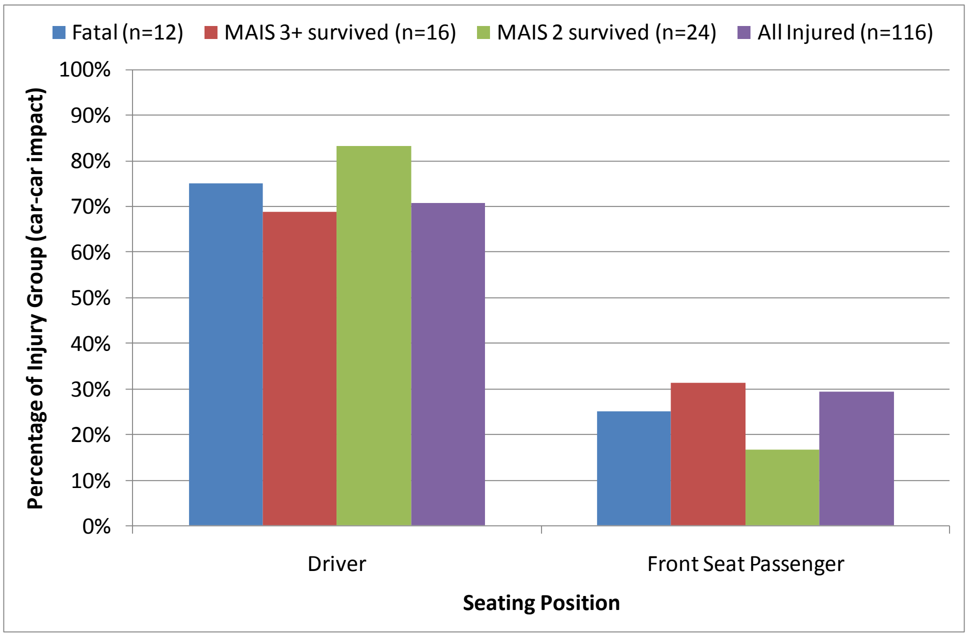



**Figure B - 18. Seating position of drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

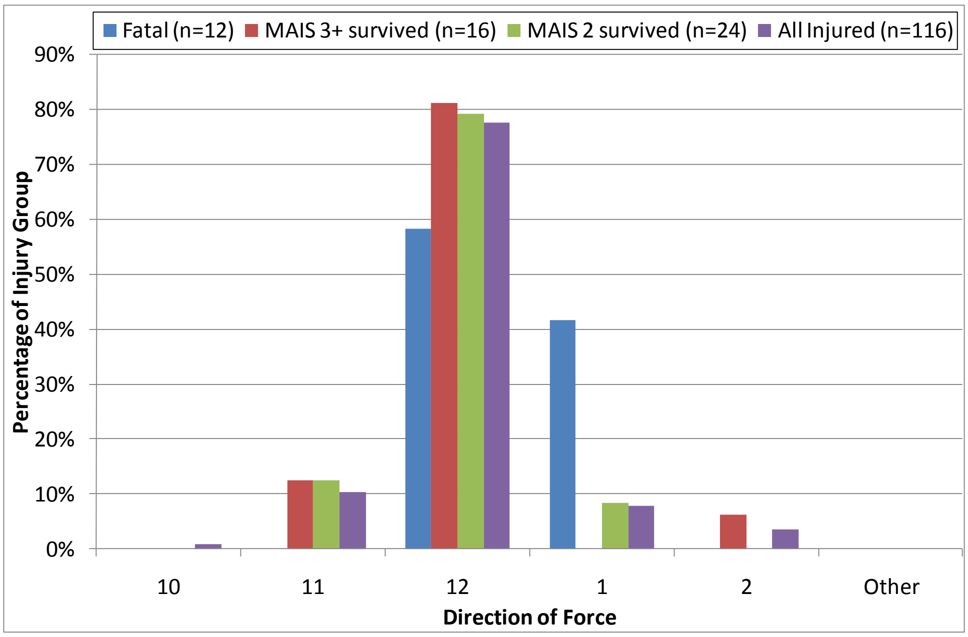



**Figure B - 19. Principle direction of force for drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

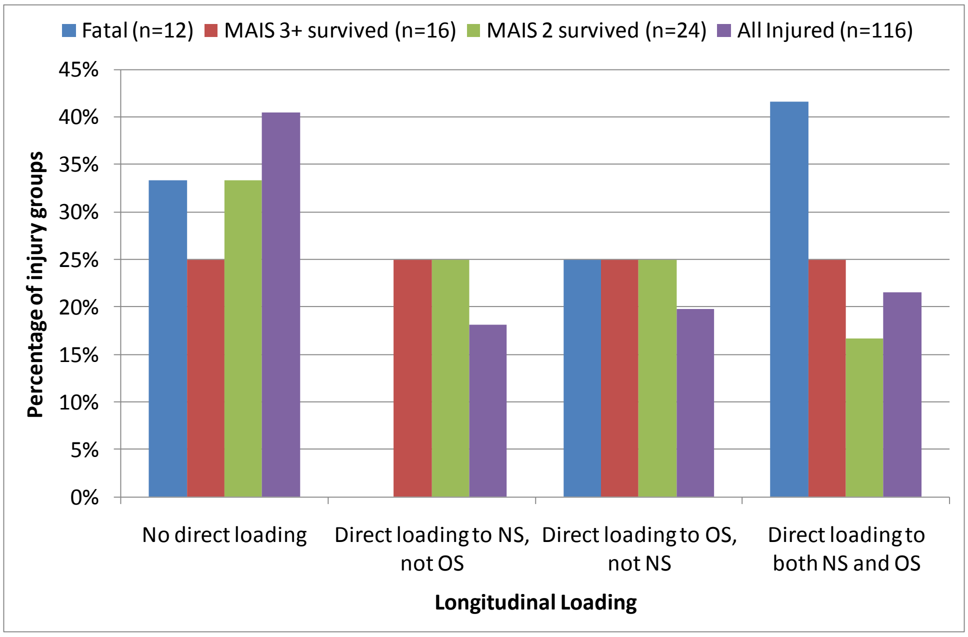



**Figure B - 20. Longitudinal loading for drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

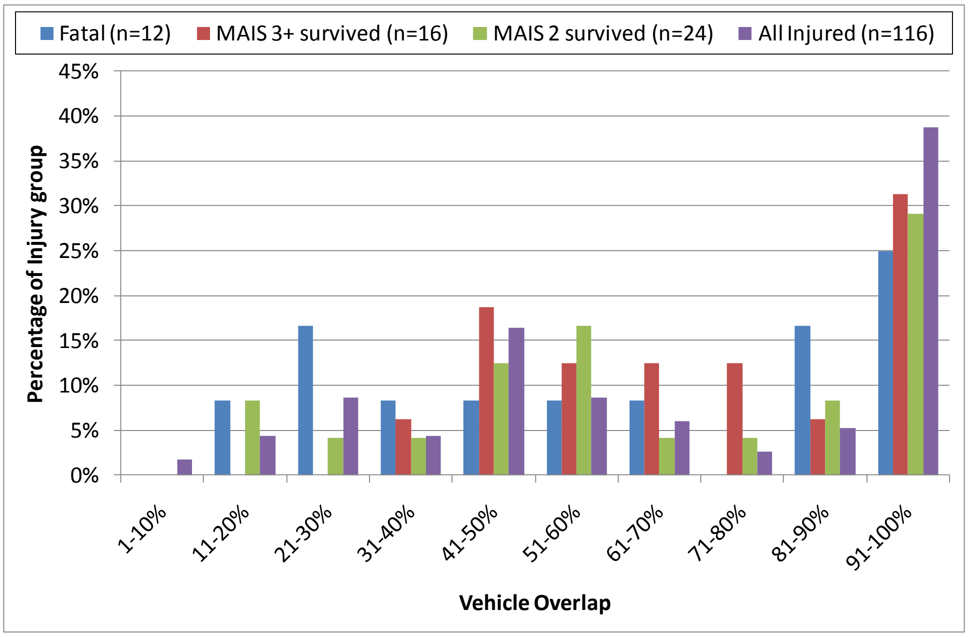



**Figure B - 21. Overlap for drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

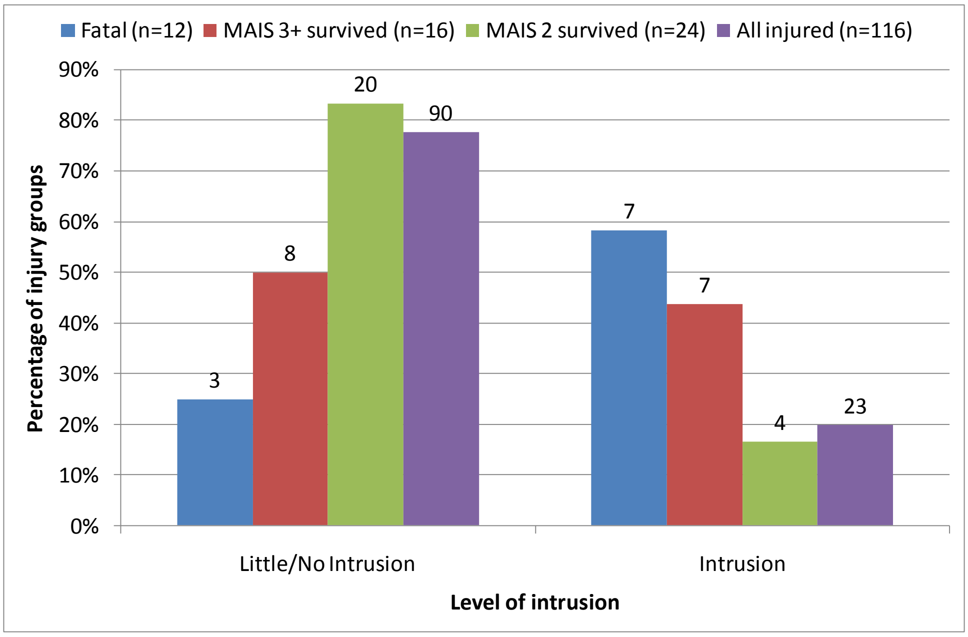



**Figure B - 22. Intrusion for drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

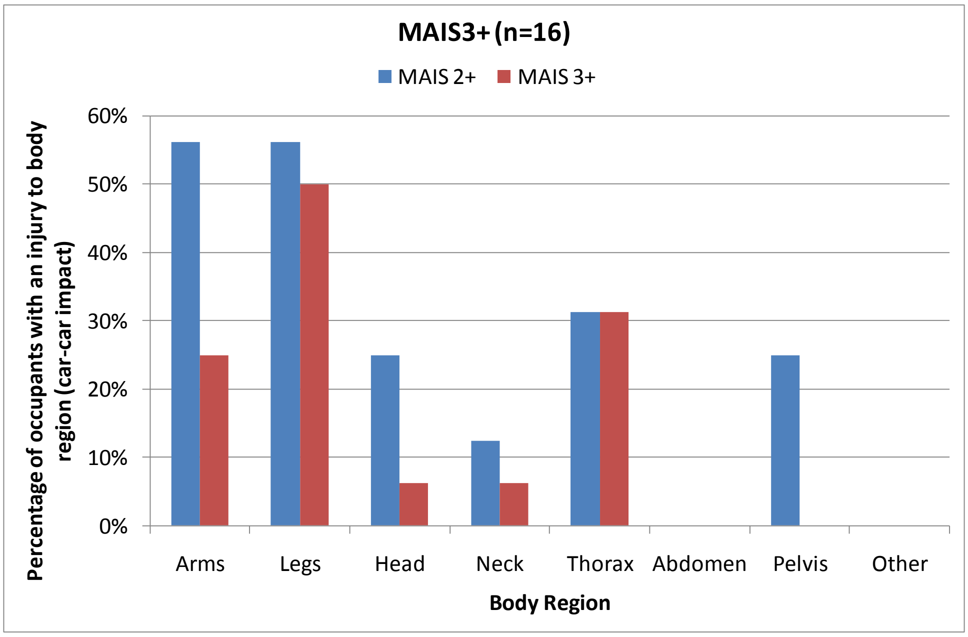



**Figure B - 23. Injury distribution for MAIS 3+ surviving drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

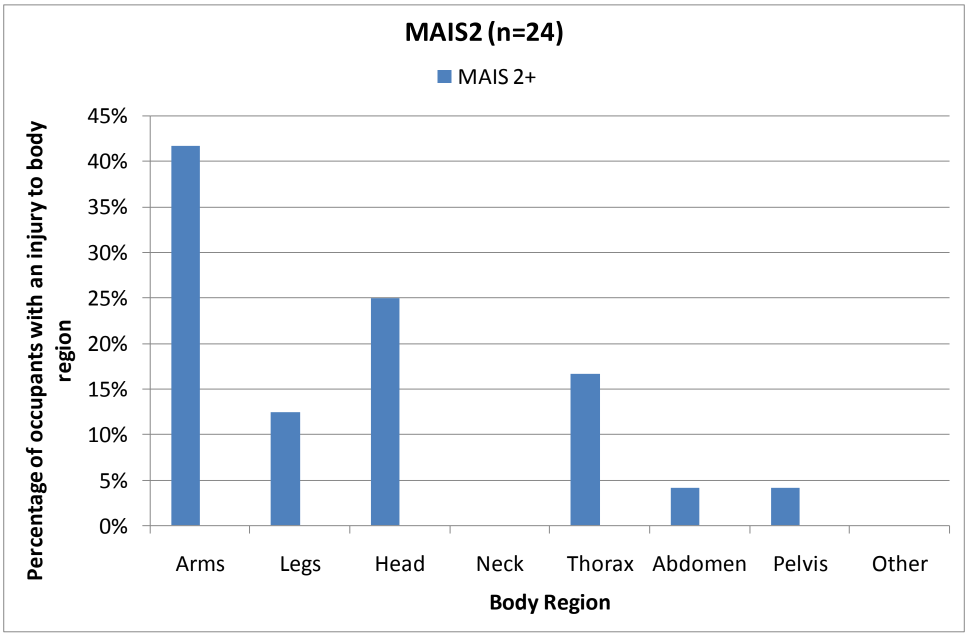



**Figure B - 24. Injury distribution for MAIS 2 surviving drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

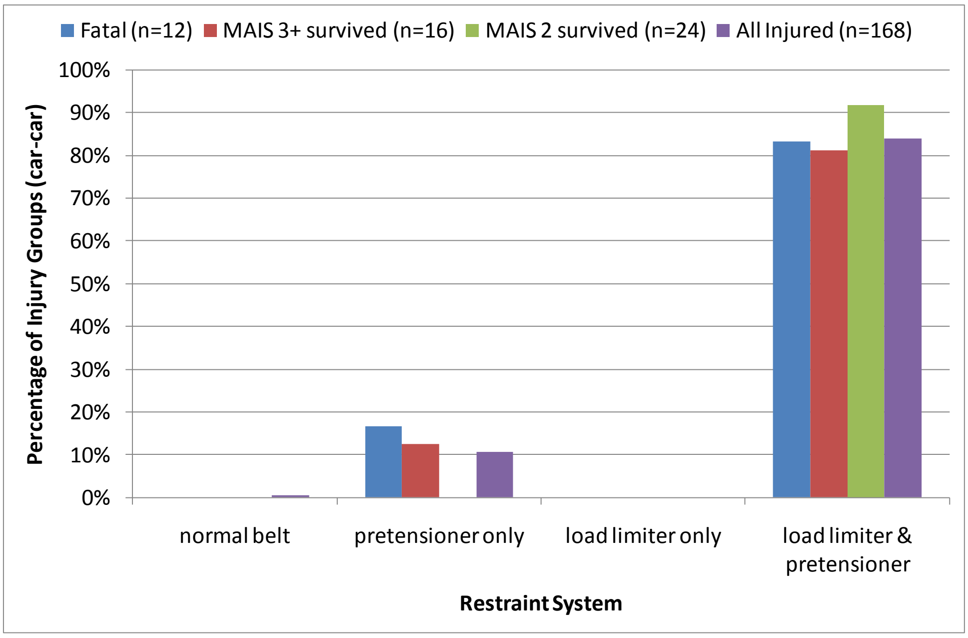



**Figure B - 25. Restraint system fitted for MAIS 2 surviving drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

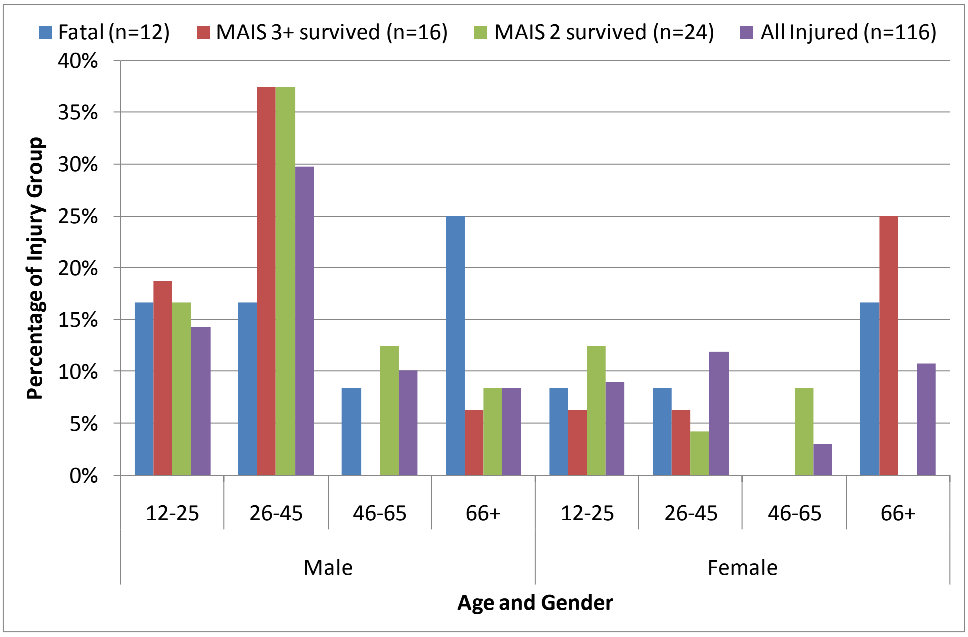



**Figure B - 26.Age and gender of drivers and front seat passengers in car-HGV/bus impacts in Great Britain**

## B.4 Drivers and front seat passengers in car-wide object impacts in Great Britain

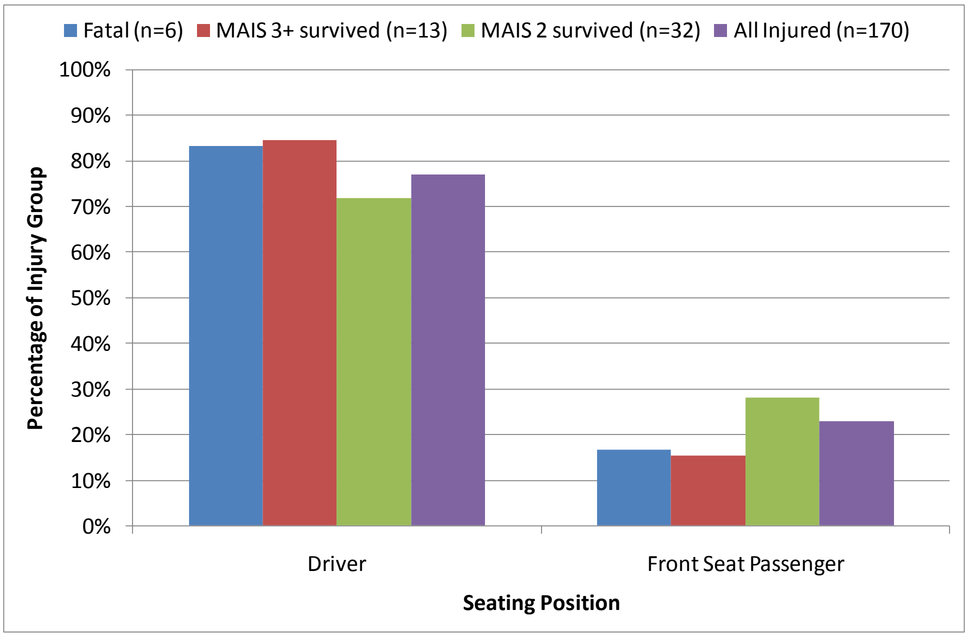



**Figure B - 27. Seating position of drivers and front seat passengers in car-wide object impacts in Great Britain**

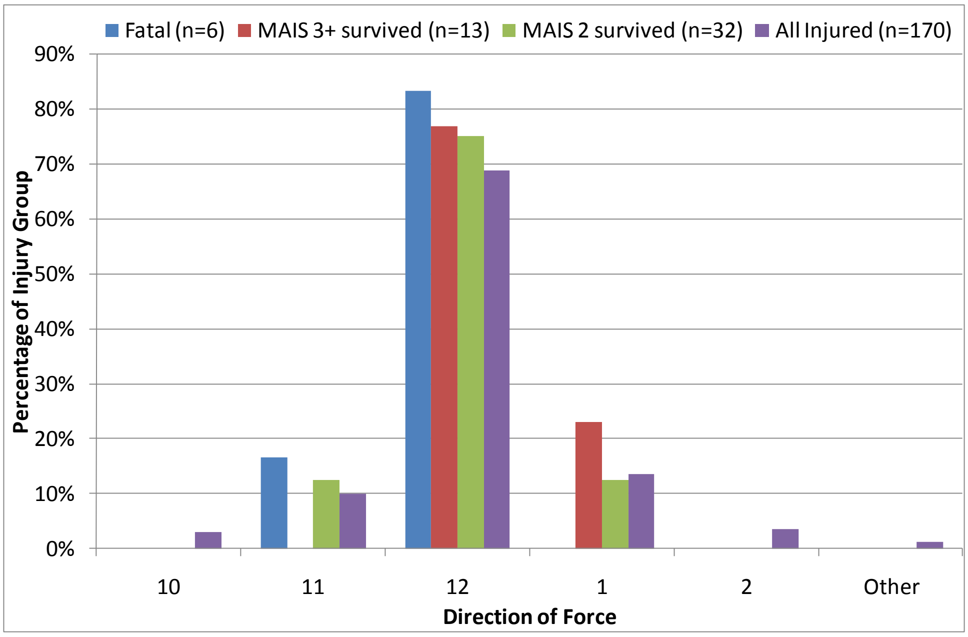



**Figure B - 28. Principle direction of force for drivers and front seat passengers in car-wide object impacts in Great Britain**

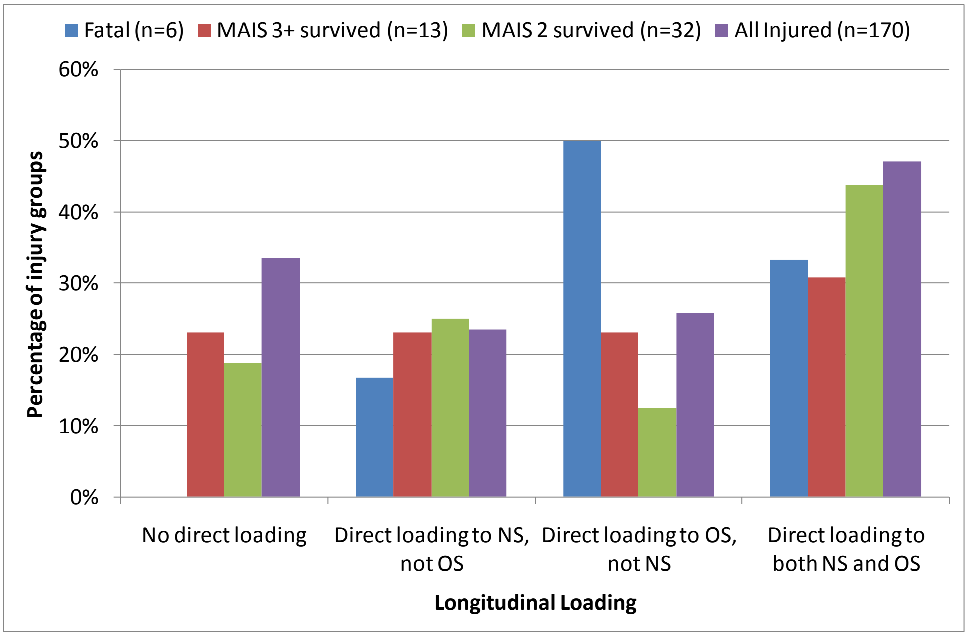



**Figure B - 29. Longitudinal loading for drivers and front seat passengers in car-wide object impacts in Great Britain**

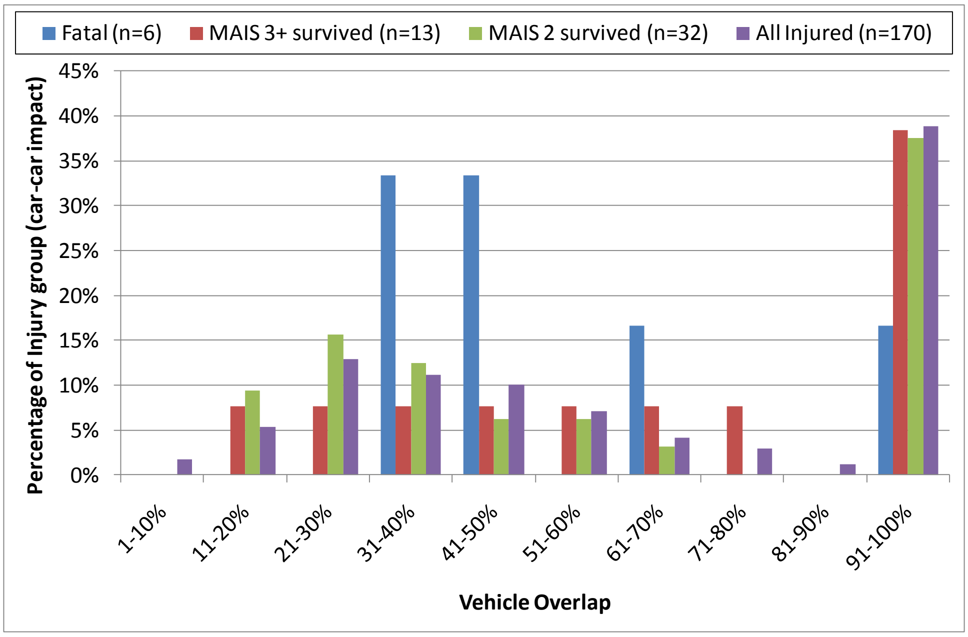



**Figure B - 30. Overlap for drivers and front seat passengers in car-wide object impacts in Great Britain**

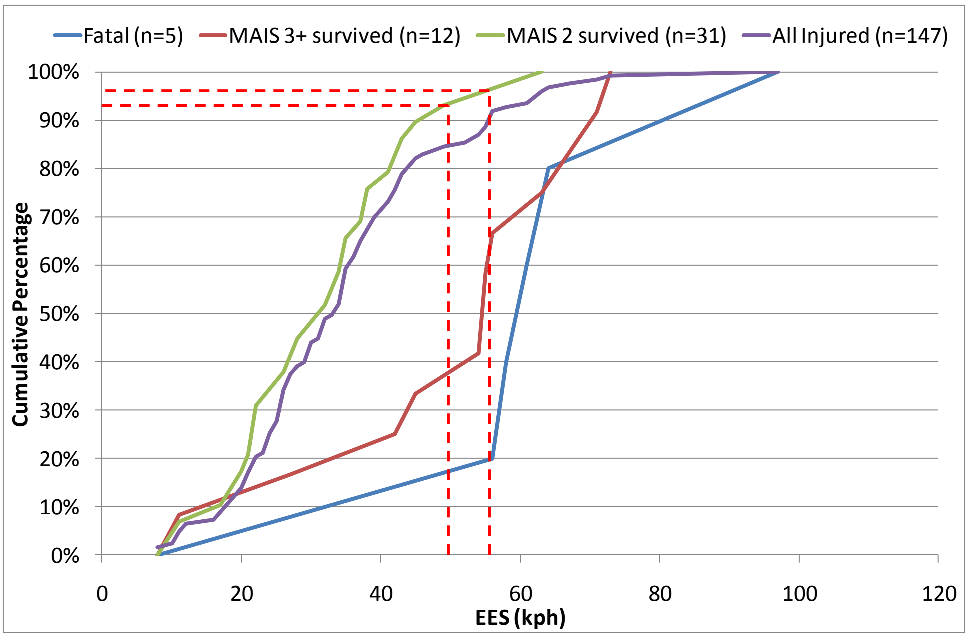



**Figure B - 31. Cumulative EES for drivers and front seat passengers in car-wide object impacts in Great Britain**

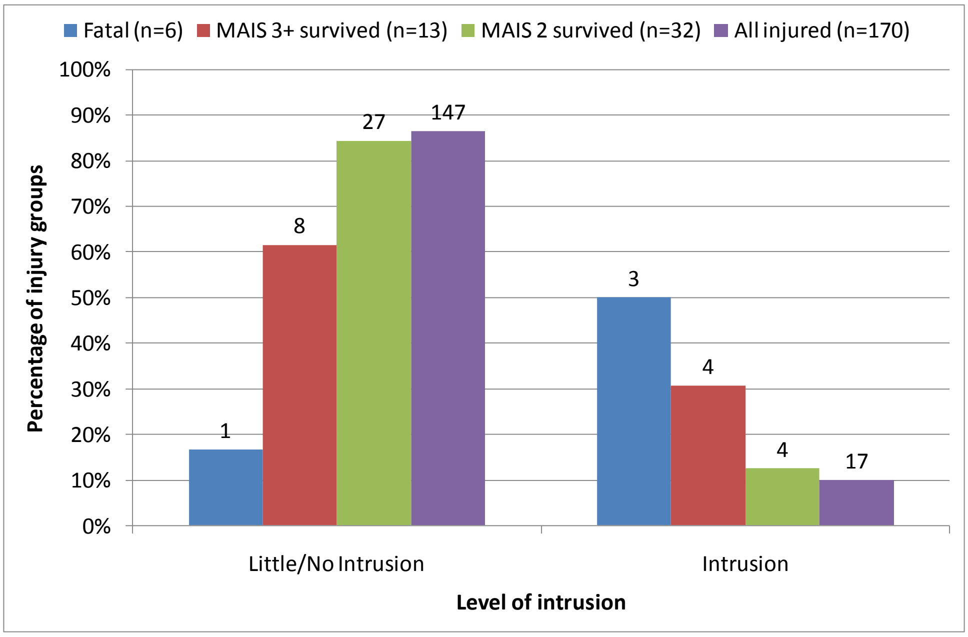



**Figure B - 32. Intrusion for drivers and front seat passengers in car-wide object impacts in Great Britain**

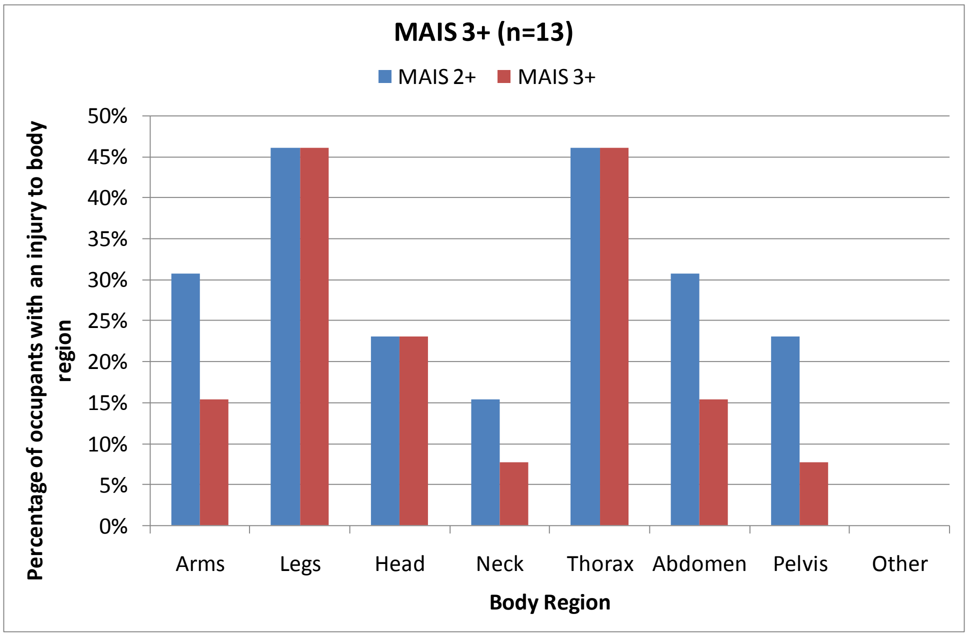



**Figure B - 33. Injury distribution for MAIS 3+ surviving drivers and front seat passengers in car-wide object impacts in Great Britain**

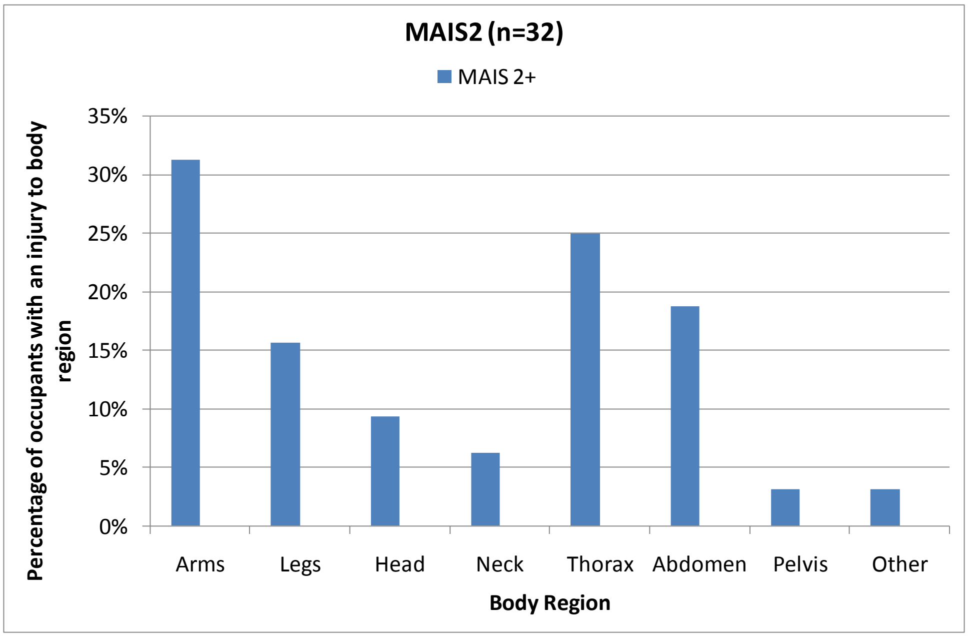



**Figure B - 34. Injury distribution for MAIS 2 surviving drivers and front seat passengers in car-wide object impacts in Great Britain**

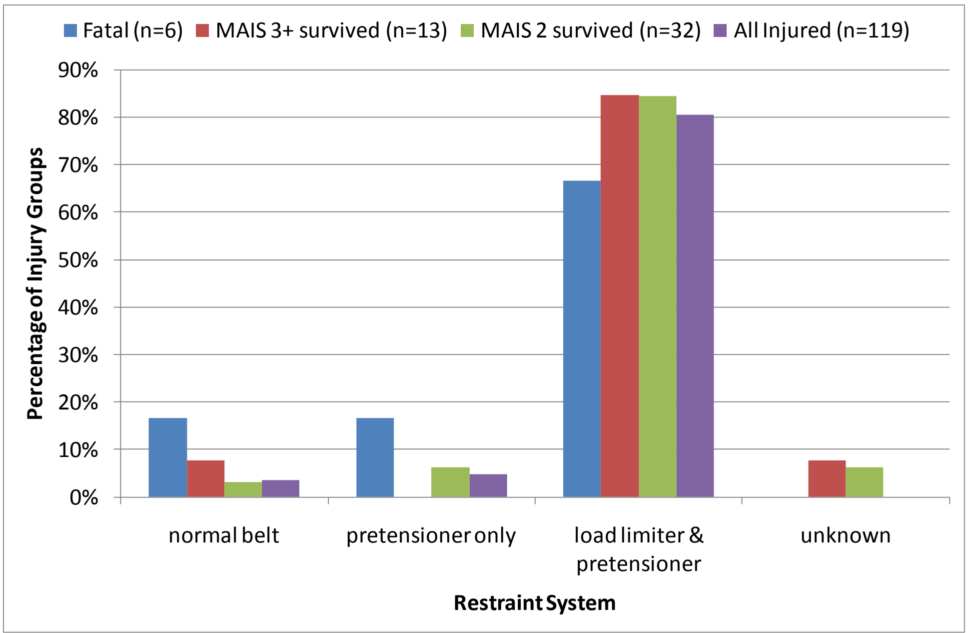



**Figure B - 35. Restraint system fitted for drivers and front seat passengers in car-wide object impacts in Great Britain**

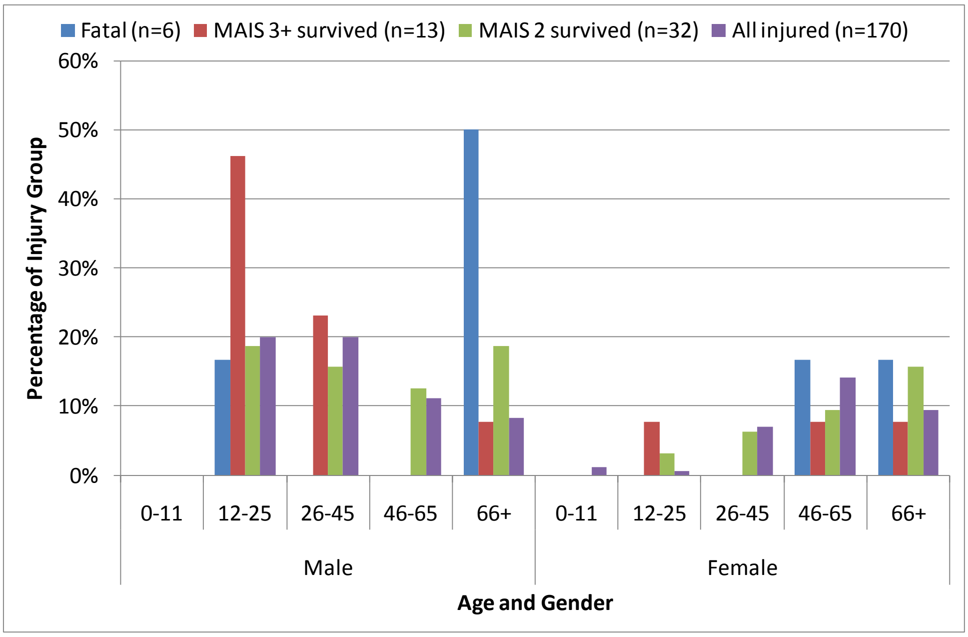



**Figure B - 36. Age and gender of drivers and front seat passengers in car-wide object impacts in Great Britain**

## B.5 Drivers and front seat passengers in car-narrow object impacts in Great Britain

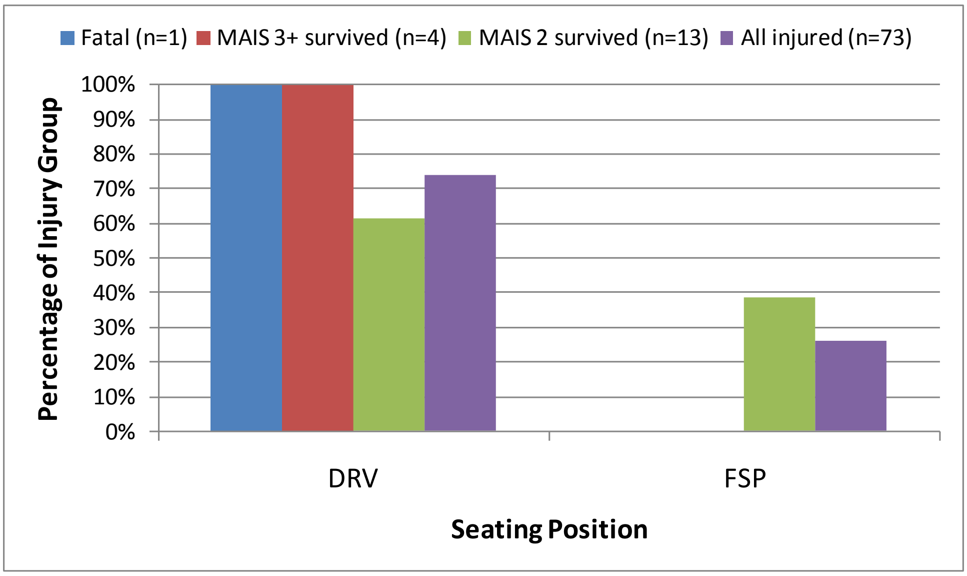



**Figure B - 37. Seating position of drivers and front seat passengers in car-narrow object impacts in Great Britain**

# Appendix C Comparing in-depth analysis from Great Britain and Germany

This section shows side-by-side the figures from Great Britain for drivers in car-car/LGV impacts, and the figures from Germany for drivers and front seat passengers in car-car/LGV impacts.

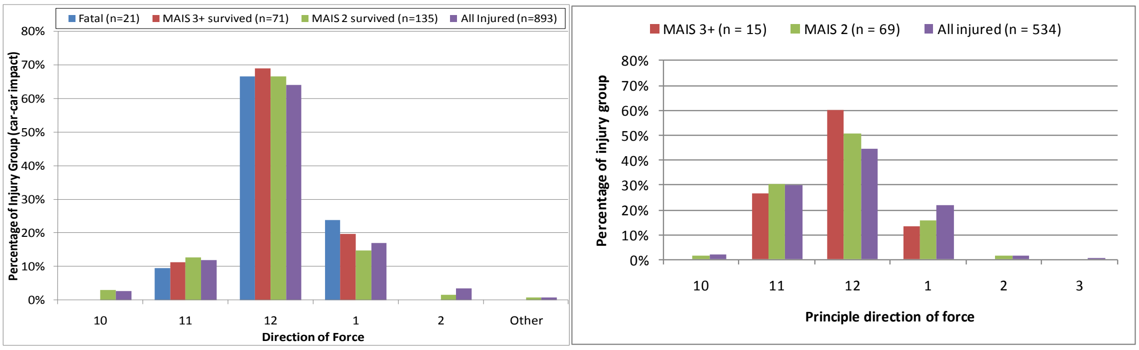



**Figure C - 1. Principle direction of force for car-car/LGV impacts in Great Britain (left) and Germany (right)**

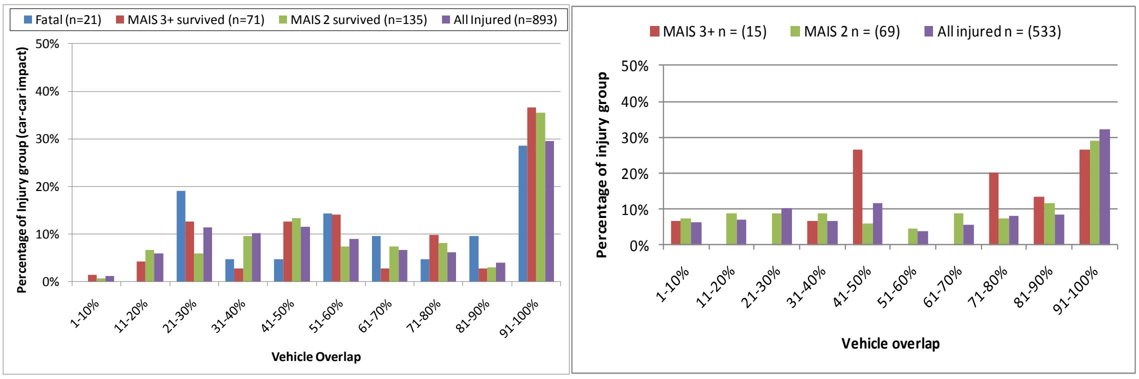



**Figure C - 2. Vehicle overlap as a percentage of injury group in Great Britain (left) and Germany (right)**

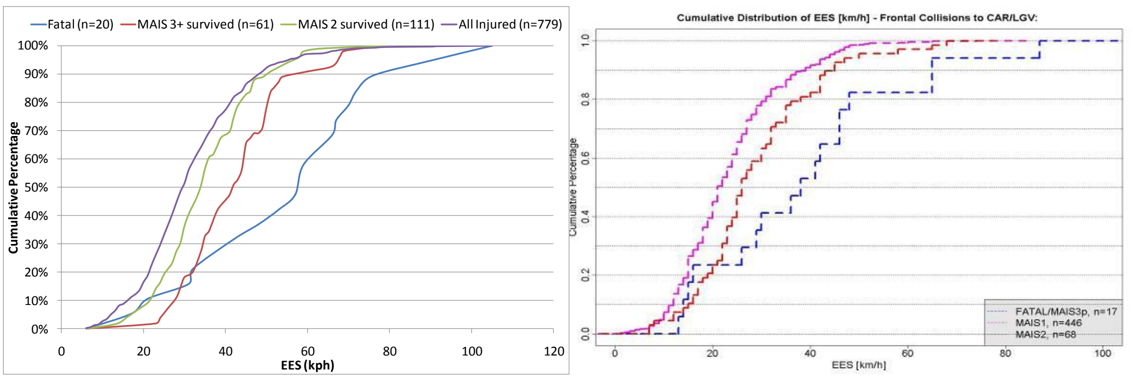



**Figure C - 3. Cumulative percentage of EES for car-car/LGV impacts in Great Britain (left) and Germany (right)**

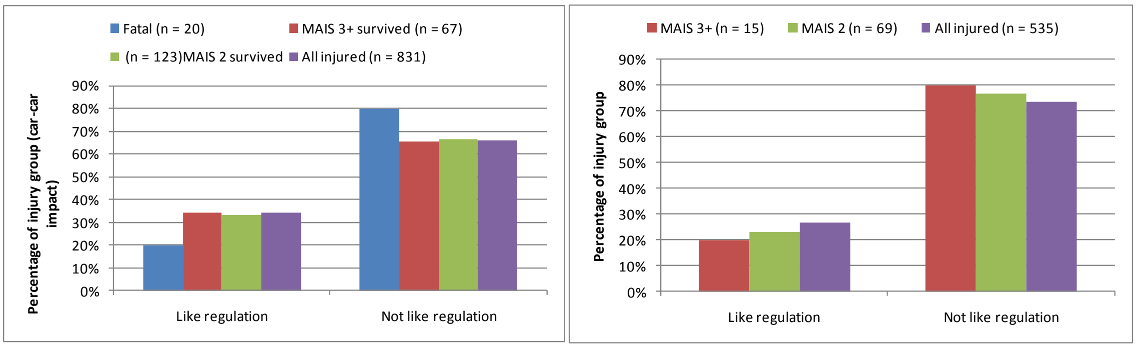



**Figure C - 4. Proportion of impacts similar to the regulatory test for car-car/LGV impacts in Great Britain (left) and Germany (right)**

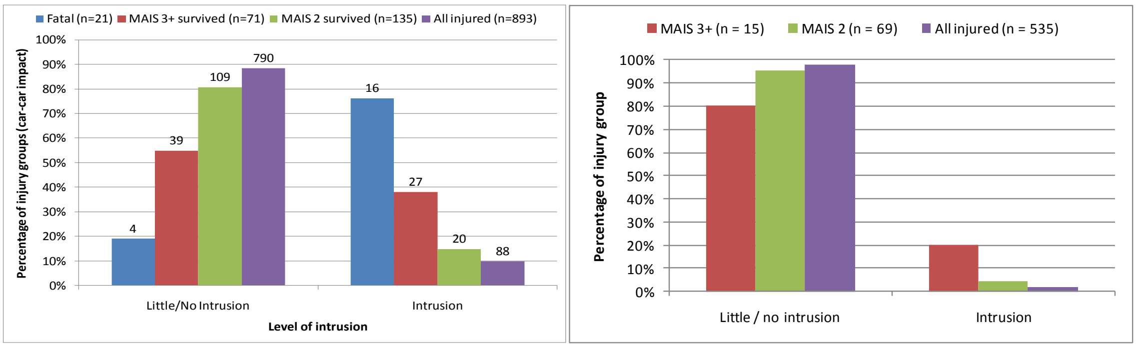



**Figure C - 5. Level of intrusion as a percentage of injury group in Great Britain (left) and Germany (right)**

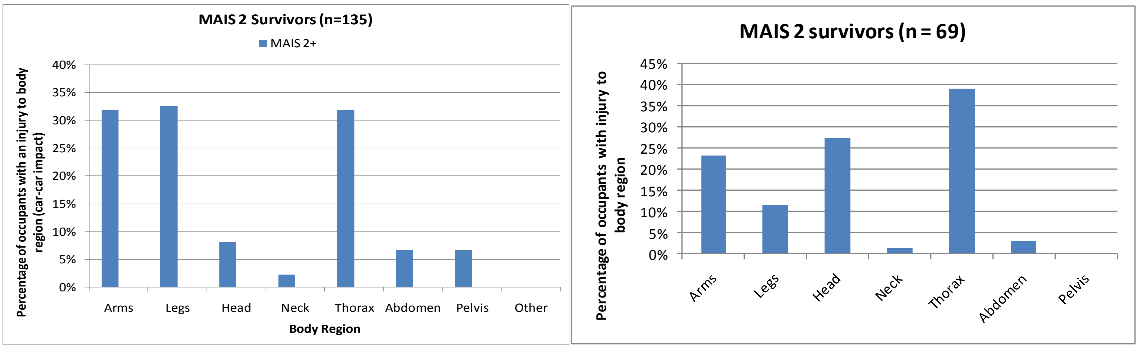
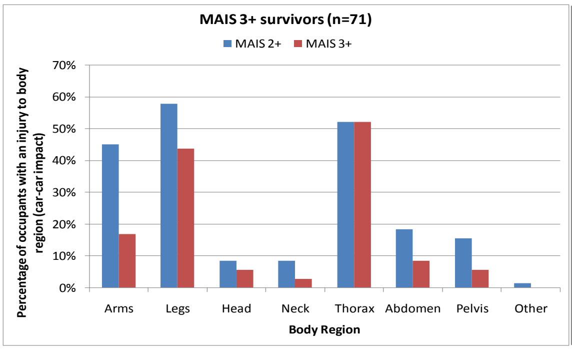



**Figure C - 6. AIS2 injury distribution for MAIS2 survivors in Great Britain (left) and Germany (right)**



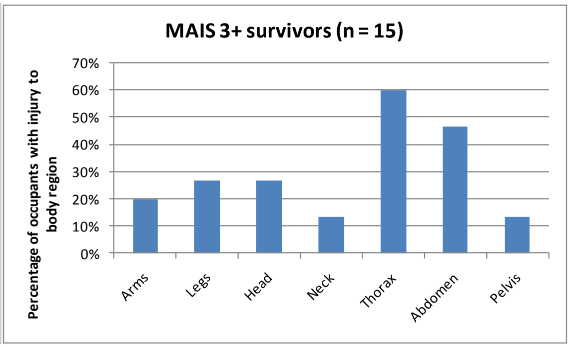
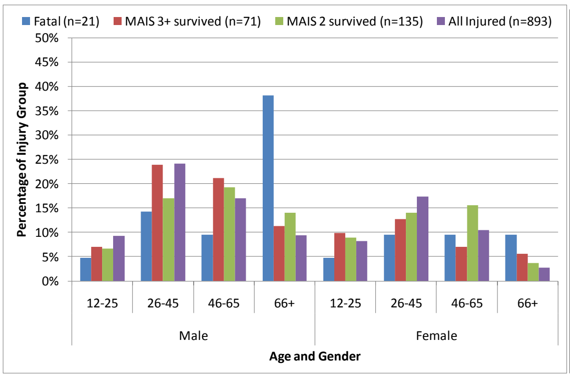




**Figure C - 7. AIS2+ injury distribution for MAIS3+ survivors in Great Britain (left) and Germany (right)**



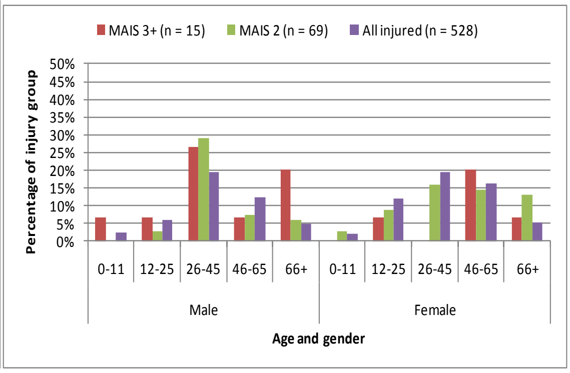




**Figure C - 8. Distribution of age and gender for car-car/LGV impacts in Great Britain (left) and Germany (right)**

# Appendix D Mass distribution

When analysing vehicle mass and compatibility, it is important to know the mass distributions of the vehicles in the sample being analysed, and the distribution of masses in the vehicle fleet. The mass distributions in the fleet and in the national accident data used in the analysis are available for France and Germany. The mass distribution for the in-depth data is available for Great Britain.

## D.1 Mass distribution in the fleet

Figure D - 1 shows the distribution of mass for the cars in the French fleet as of December 2007. This shows the mass distribution for all vehicles, and for those which were and were not Regulation 94 compliant. Figure D - 2 shows the mass distribution for cars in the German fleet in 2007, and shows the mass distribution for the French fleet so that they can be compared easily.

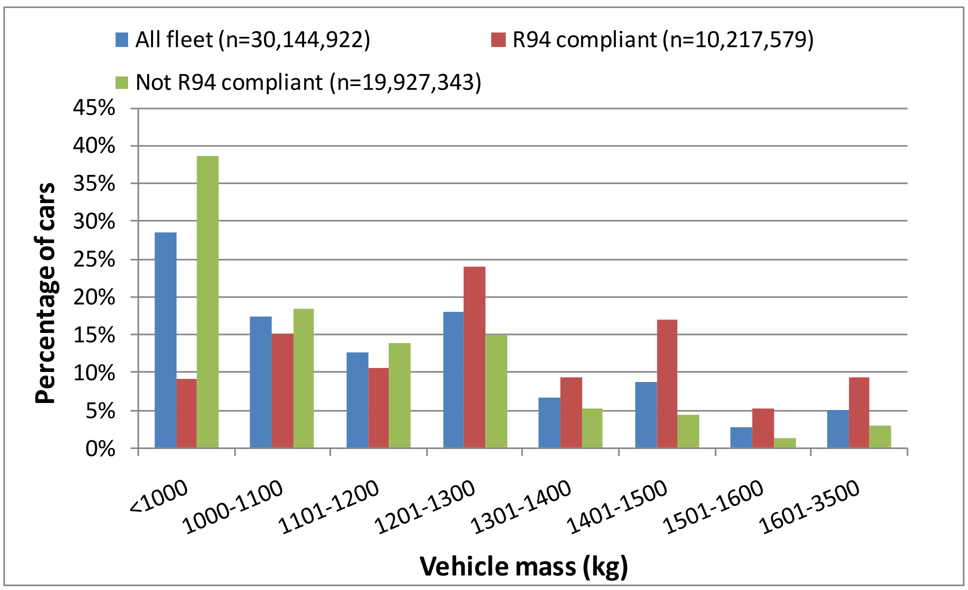



**Figure D - 1. distribution of cars in France in 2007**

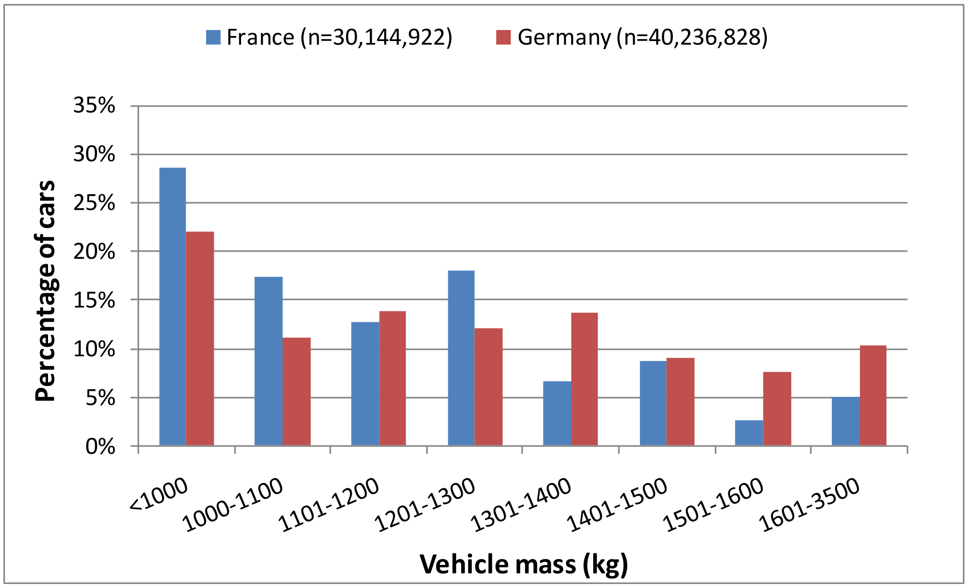



**Figure D - 2. Mass distribution of cars in France and Germany in 2007**

The mass distribution of Regulation 94 compliant cars in France is very different to the mass distribution for the entire fleet. There is a far lower proportion of Regulation 94 compliant cars with a mass under 1000 kg, and a higher proportion of Regulation 94 cars with a mass above 1200 kg.

The mass distribution of vehicles in France and Germany are also different – France has a higher proportion of cars under 1000 kg, and Germany has a higher proportion of vehicles with a mass greater than 1300 kg.

## D.2 Mass distribution in the accident samples

Figure D - 3 shows the distribution of vehicle mass for the two samples from the French national accident data which have been used in the analysis in this section: Regulation 94 compliant vehicles involved in a frontal impact with another Regulation 94 compliant vehicle; and Regulation 94 vehicles involved in a frontal impact with an object in a single vehicle accident. The differences in the mass distribution of these two samples are statistically significant, however there is a similar pattern in both datasets. The lighter vehicles appear to be more frequent than the heavier vehicles in single vehicle crashes.

This is in contrast to the distribution of vehicle mass in the Regulation 94 compliant car fleet in France, where cars with a mass of 1,201-1300kg were most frequent and there was a much smaller proportion of vehicles with a mass less than 1000kg.

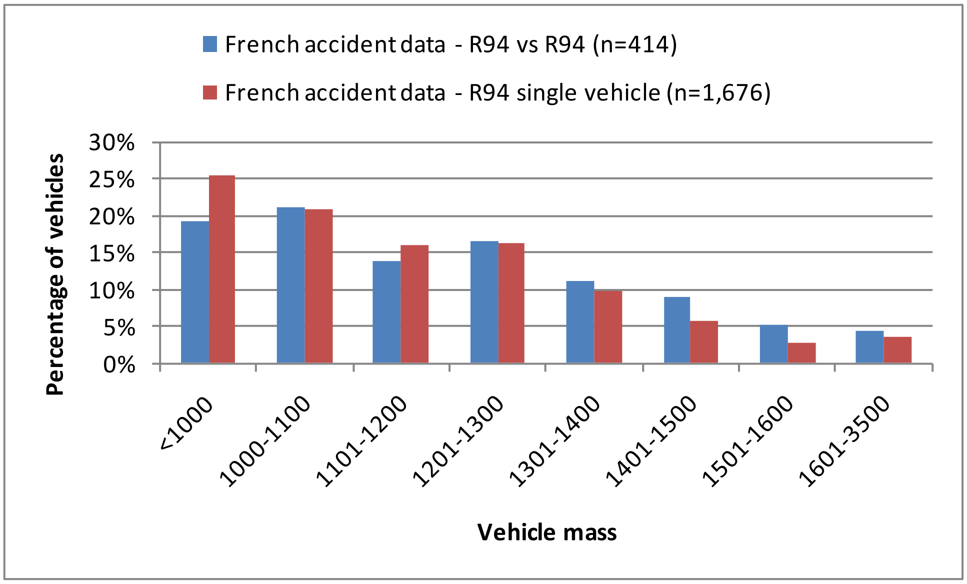



**Figure D - 3. Distribution of vehicle mass in French national accident data**

Figure D - 4 shows the mass distribution of the cars in the national accident data from Germany for the Regulation 94 compliant cars. This distribution is very similar to the mass distribution for all cars in the vehicle fleet in Germany – cars with a mass less than 1000kg are the most frequent group in both datasets.

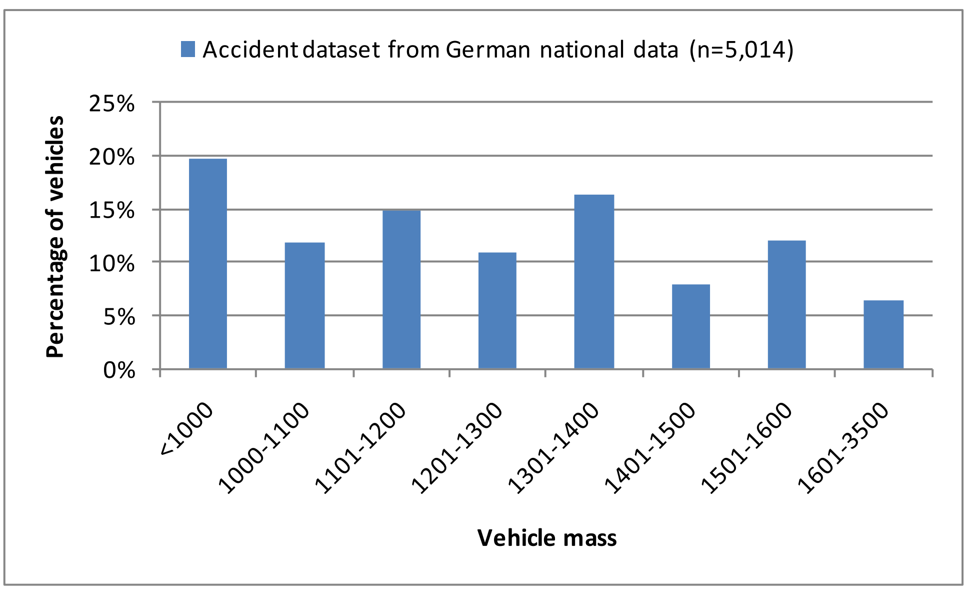



**Figure D - 4. Mass distribution of cars in dataset from German national accident data**

The distribution of vehicle mass in the in-depth dataset from Great Britain (CCIS) is shown in Figure D - 5. This is for the Regulation 94 compliant cars in the dataset which had front-front impacts with other Regulation 94 compliant cars.

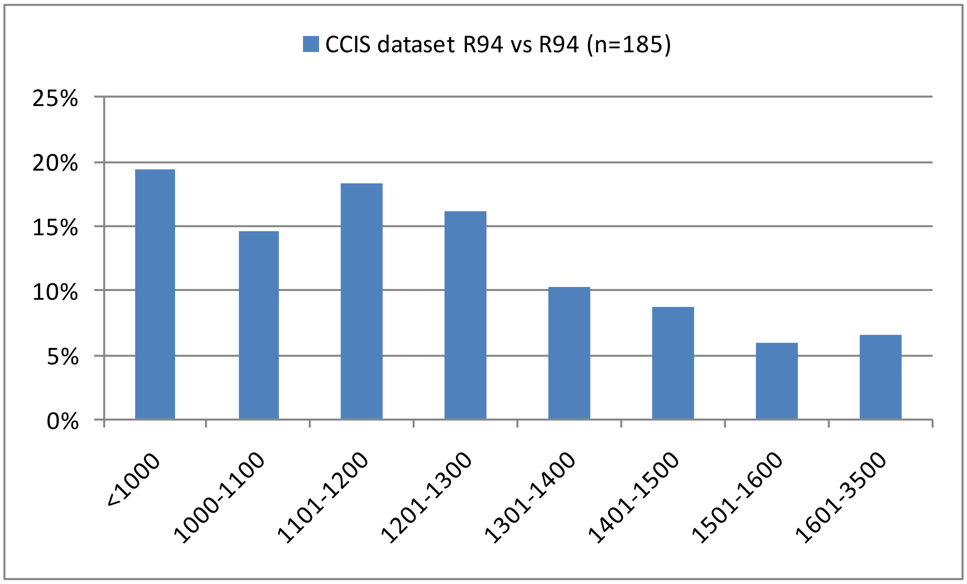



**Figure D - 5. Mass distribution of cars in in-depth dataset for Great Britain**

## D.3 Summary

The mass distribution of the vehicle fleet was available for France and Germany. This enabled comparison between the two countries, comparison of the mass distribution of R94 compliant cars and non-R94 compliant cars, and comparison between the mass distribution in the fleet and the accident sample.

- The mass distribution of the whole vehicle fleet, and Regulation 94 compliant cars, was available for France. Comparison of the two showed that there is a far smaller proportion of Regulation 94 compliant cars with a mass below 1000 kg, and a higher proportion with masses over 1200 kg.
- Comparison of the mass distribution of the whole car fleet in Germany and France showed that there are fewer light vehicles but more heavy vehicles in the German fleet. It is not clear why this is the case, although it could be related to the proportion of vehicles which are Regulation 94 compliant in the two countries.
- The distribution of vehicle mass in the French accident data is different to the distribution in the Regulation 94 compliant fleet. In the accident data there are fewer lighter vehicles and more heavy vehicles. However, in Germany, the fleet and accident mass distributions are similar.