J. Lenard, A. Morris, J. Barnes
VSRC Loughborough University, UK

E. Tomasch
Technical University of Graz, Austria

J. Nehmzow, D. Otte
Medical University of Hannover, Germany

L. Cant, M. Haddak, G. Vallet
INRETS, Lyon, France

H. Ebbinger
Chalmers University, Gothenburg, Sweden

Y. de Vries
TNO, Delft, The Netherlands

B. van Kampen
SWOV, The Hague, The Netherlands

J. Paez
INSIA-UPM, Madrid, Spain

PENDANT: A European Crash Injury Database

Abstract

Annually within the European Union, there are over 50,000 road accident fatalities and 2 million other casualties, of which the majority are either the occupants of cars or other road users in collision with a car. The European Commission now has competency for vehicle-based injury countermeasures through the Whole Vehicle Type Approval system. As a result, the Commission has recognised that casualty reduction strategies must be based on a full understanding of the real-world need under European conditions and that the effectiveness of vehicle countermeasures must be properly evaluated.

The PENDANT study commenced in January 2003 in order to explore the possibility of developing a co-ordinated set of targeted, in-depth crash data resources to support European Union vehicle and road safety policy. Three main work activity areas (Work Packages) commenced to provide these resources. This paper describes some of the outcomes of Work Package 2 (WP2, In-depth Crash Investigations and Data Analysis).

In WP2, some 1,100 investigations of crashes involving injured car occupants were conducted in eight EU countries to a common protocol based on that developed in the STAIRS programme. This paper describes the purposes, methodology and results of WP2. It is expected that the results will be used as a co-ordinated system to inform European vehicle safety policy in a systematic, integrated manner. Furthermore, the results of the data analyses will be exploited further to provide new directions to develop injury countermeasures and regulations.

1 Introduction

Annually within the European Union, there are over 50,000 road accident fatalities and 2 million other casualties. The majority of these are either the occupants of cars or other road users in collision with a car. Through the Maastricht Treaty the European Commission now has competency for vehicle-based countermeasures through the Whole Vehicle Type Approval system. Casualty reduction strategies must be based on a full understanding of the real-world need under European conditions and their effectiveness must be properly evaluated. There is however no co-ordinated mechanism available to the Commission to provide a suitable resource with which to support new safety actions and to provide feedback. A major gap concerns the availability of pan-European data on injuries and their causation for qualitative and quantitative support for European policy.

As described in the STAIRS project [1], a single European-wide crash injury database would be of exceptional benefit to the legislative process at EU level. A direct data-driven approach would allow identification of any safety problems at an early stage and would facilitate quick and accurate evaluation of new technologies and remedial measures, including legislation, that may have been implemented. The overall aim of the STAIRS project was to take the first steps towards this goal. The project involved standardisation of in-depth road accident data collection methodologies which would provide the core framework for any pan-European crash injury studies. This included specification of a number of key data variables, case selection criteria and general investigative approach.

At the conclusion of the STAIRS project, the EC stated that there was general support in principle for the implementation of its recommendations, albeit with certain barriers that needed to be overcome. There was a suggestion that the EC's 5th Framework programme could incorporate an additional stage beyond STAIRS whereby the basic building blocks of STAIRS could be implemented on a limited basis. This would include validation of the main recommendations, an assessment of its usefulness and determination of its limitations. This set the scene for the development of a major element of work which became Work Package 2 of the PENDANT (Pan-European Co-ordinated Accident and Injury Databases) project.

The aim of Work Package 2 was to bring together the resources and infrastructures of existing accident and injury investigation groups to build a demonstration European crash injury database. It was the intention that the database could be continued and enhanced after the completion of this project to become a central European resource which would facilitate road and vehicle safety decisions and policy making. It was also the intention that the database would be used to examine the injury prevention priorities for future action and to provide feedback to European casualty reduction measures such as the EuroNCAP rating system.

Following the final development of the standardised demonstration database system to facilitate data entry and combined analysis, further objectives of PENDANT Work Package 2 included (a) to investigate at least 1,100 accidents involving injured car occupants or pedestrians and compile the data into the database, and (b) to analyse the composite database and identify priorities for future European regulatory and other action. The methodology of PENDANT data collection, sample results from analysis of the database, and priorities identified for future action are described in the following sections of this paper.

2 Methodology

At the outset of the PENDANT study, the EC comprised 15 member states. Groups from 8 of these countries participated in in-depth crash injury data collection, with sample areas in northern, central and southern Europe to give a range of accident conditions that was as representative as possible. These organisations were Technical University of Graz (Austria), University of Turku/VALT (Finland), INRETS, CETE-SO and ARVAC (France), Medical University of Hannover (Germany), TNO and SWOV (the Netherlands), UPM-INSIA (Spain), Chalmers University (Sweden) and Loughborough University (UK).

The basic data collection protocol, including the specification of the core data to be gathered, was developed within the earlier STAIRS project that was completed in March 1999. It mainly relates to passive safety. This protocol was developed into appropriate data collection forms that were updated to take into account technology developments. Some additional fields were included to provide an overview of accident causation events, although not in great detail, as this was not the main purpose of the project.

It was intended that a special feature of the data would be the case selection methodology which would be targeted on newer vehicles to efficiently provide data that has value for regulation and safety countermeasures. The accident selection criteria for inclusion in the database were accordingly set as follows:

- M1 and N1 Passenger vehicles manufactured on or after 1st January 1998 involved in crashes with other passenger vehicles (providing that injury occurred in either vehicle).
- M1 and N1 Passenger vehicles manufactured on or after 1st January 1998 involved in crashes with other non M1/N1 vehicles (e.g. trucks/buses) providing injury occurred to at least one occupant of the passenger vehicle.
- M1 and N1 Passenger vehicles manufactured on or after 1st January 1998 involved in single-vehicle crashes (e.g. pole, tree, and rollover).
- 20% of accidents from each data collection centre to be of MAIS 3+ injury severity. The remaining accidents to be sampled randomly from the geographical regions in which teams operate.
- A maximum of 10% of the required case-load for each partner could comprise pedestrian crashes.

In general, all teams adopted similar data collection procedures although some differences were apparent. The main system of crash notification was via the police. Some teams investigated accidents immediately on receipt of notification whilst other teams investigated cases in the days after the crash. The sample regions may be broadly characterised as Graz region (Austria), Southwest Finland, Uusimaa and Ita-Uusimaa (Finland), Departement du Rhône (France), Lower Saxony (Germany), Zuid-Holland (the Netherlands), Madrid region (Spain), Vastra Gotaland (Sweden) and the East Midlands (UK).

3 Results

The PENDANT project contains an analytic component which has produced a large number of results on a variety of topics. A number of analytical outputs are included as 'Deliverables' which will be publicly available in the near future. In this paper it is only possible to provide a short selection of these, touching on overall statistics, frontal collisions, rear-end impacts, rollovers, pedestrian impacts, injury costing and EuroNCAP test conditions. Much more data will be available from the analytical outputs.

3.1 Overview

The overall number of cases on the database is shown in Table 1. It contains records for 1110 accidents, 1884 vehicles, 2369 occupants and 68 pedestrians. The relatively small proportion of vehicles or humans for which no information could be collected or recorded on the database is not included in these tallies. The number of accidents to be supplied from each group was decided prior to data collection based on resources and capability.

	Accident	Vehicle	Occupant	Pedestrian
Sweden	150	264	355	0
France	132	201	296	0
Germany	171	328	424	21
Austria	75	152	229	8
Netherlands	175	326	235	18
United Kingdom	200	290	445	2
Finland	80	126	153	6
Spain	127	197	232	13
Total	1110	1884	2369	68

Table 1: Number of cases on PENDANT database

	Car	Truck	Bus	Agricultural vehicle	Two-wheel vehicle
Sweden	248	10	6	0	0
France	194	6	0	0	1
Germany	319	9	0	0	0
Austria	144	8	0	0	0
Netherlands	306	13	3	2	2
United Kingdom	272	11	2	1	4
Finland	117	7	2	0	0
Spain	181	9	3	2	2
Total	1781	73	16	5	9

Table 2: Vehicle type

The types of vehicles on the database are shown in Table 2. The high proportion of passenger cars reflects the sampling criterion that a passenger car (manufactured from 1998 on) had to be involved in each accident.

Figure 1 shows the maximum level of injury for selected types of crashes. The proportion of serious and fatal casualties on the database is high due to the sampling requirement that at least 20% of accidents should be of MAIS 3+ severity. Some parked vehicles were unoccupied.

3.2 Frontal crashes

The tables in this section relate to two-car collisions in which the main impact was to the front end of both vehicles. There were 104 accidents of this type (necessarily) involving 208 vehicles.

The change of velocity during impact (delta-V) was calculated for 166 vehicles. The distribution of delta-V shown in Figure 2 indicates that 45% of impacts were in the 21-40km/h range.

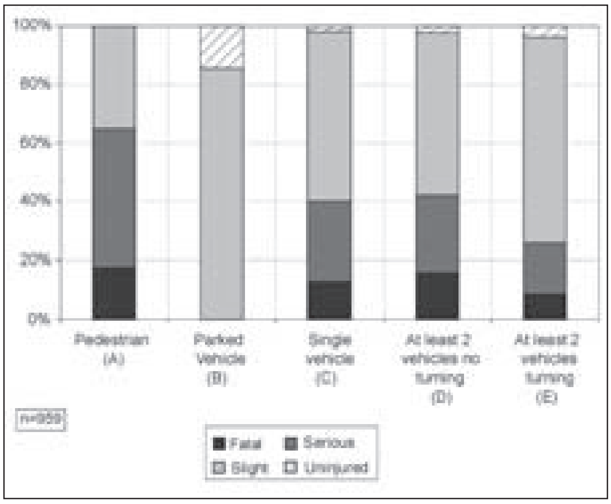

Figure 1: Crash type by injury severity

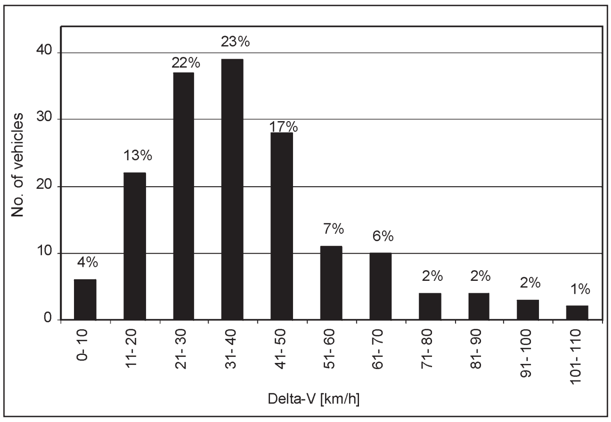

Figure 2: Change of velocity during impact for frontal crashes

Figure 3 shows the number and severity of injuries by body region according to whether there was intrusion into the vehicle or not. Very few AIS 3+ injuries occurred without intrusion, most exceptions being to the head. It does not follow that intrusion is necessarily a causal factor, as intrusion correlates with impact severity and impact severity – or more specifically the acceleration of the vehicle during impact – an result in injury independently.

Figure 4 shows the distribution of injuries by AIS severity for vehicles manufactured before 1998 (old) or from 1998 onwards (new). The proportion of AIS 3+ injuries is greater in pre-1998 vehicles, suggesting improved crashworthiness in modern vehicles.

3.3 Rear impacts

The database contains 80 cars that were struck in the rear from another vehicle, excluding two-wheelers.

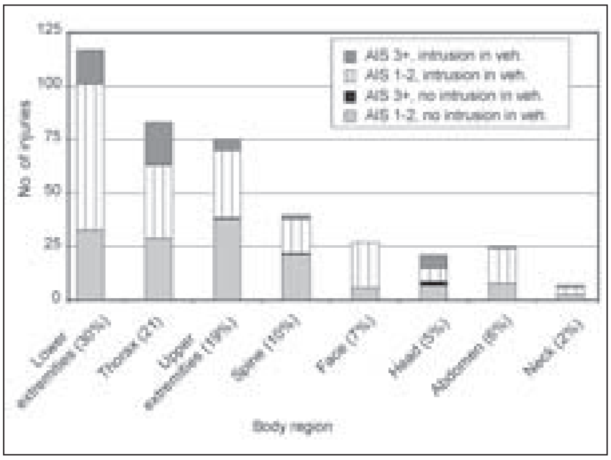

Figure 3: Number of injuries by body region for frontal crashes

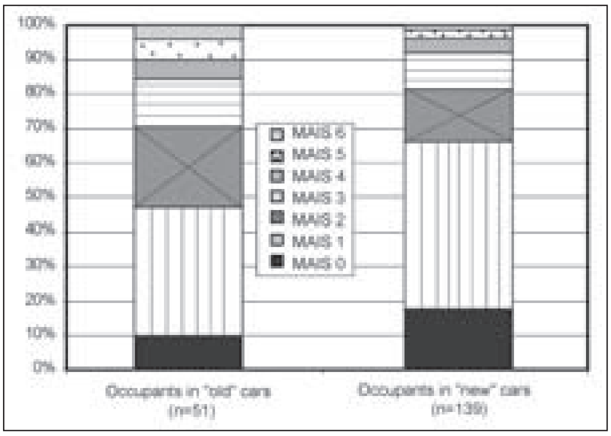

Figure 4: Distribution of MAIS by vehicle age for frontal crashes

Figure 5 shows the number of injuries by body region for males and females. The spine is by far the region most frequently affected, proportionally more often for females than males. This supports numerous studies with a similar finding.

3.4 Rollovers

There are 199 cars on the database which turned 90 degrees or more on the vehicle's longitudinal or lateral axis during the course of the accident. These events are interpreted as rollovers.

Rollovers may occur with or without significant impacts to other vehicles or roadside objects. In Figure 6 the distribution of MAIS for injured occupants is shown for non-rollovers (n=1041), rollovers without other impacts (n=65) and rollovers with other impacts (n=134).

Figure 7 shows that the proportion of vehicles in rollovers with electronic stability control (8.5%) is lower than the proportion of vehicles not fitted with this type of technology (17.9%).

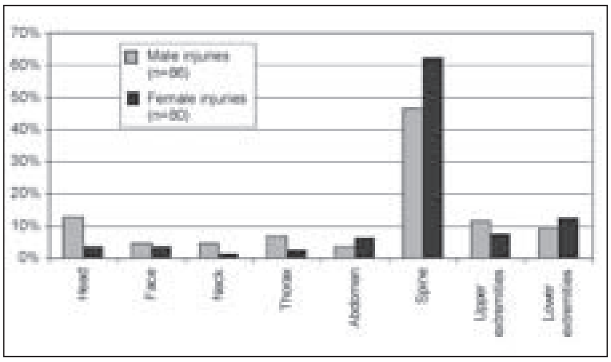

Figure 5: Number of injuries by body region for rear impacts

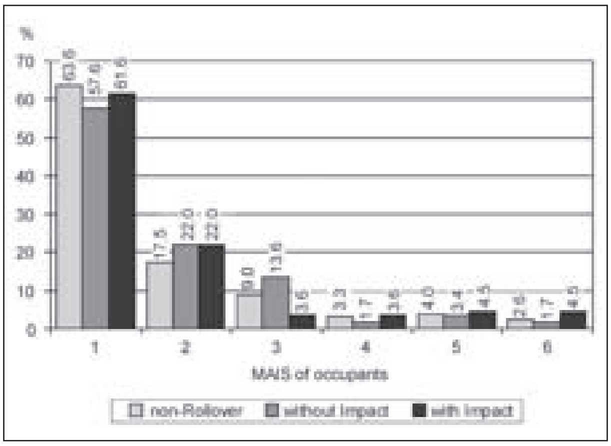

Figure 6: Occupant MAIS distribution with rollover and further impacts

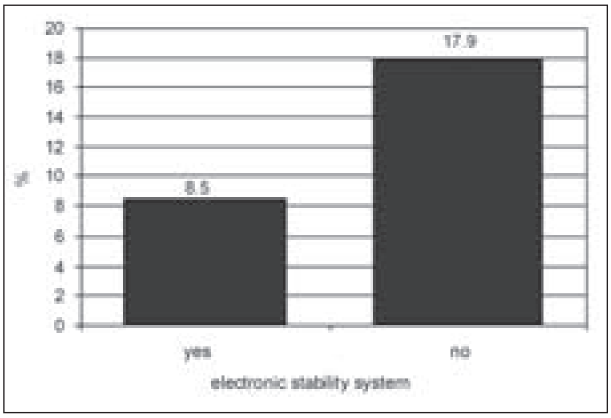

Figure 7: Proportion of vehicles with electronic stability control in rollovers

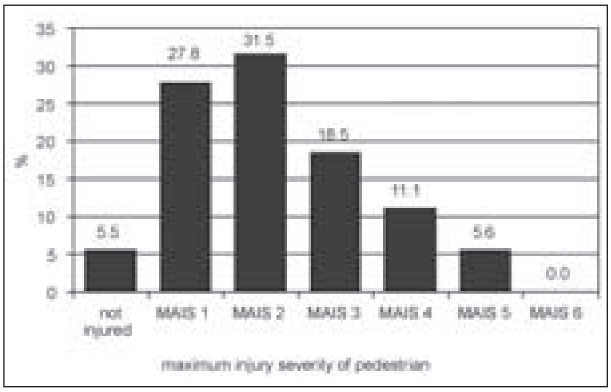

Figure 8: Pedestrian MAIS distribution

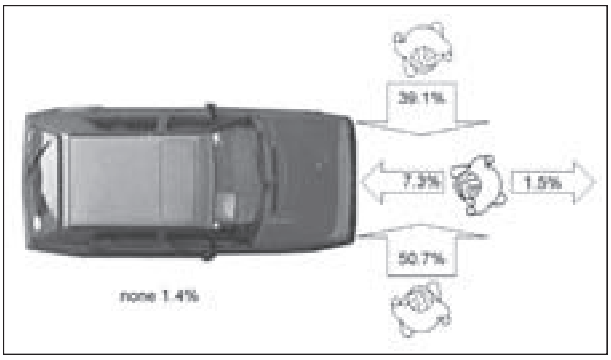

Figure 9: Walking direction (n=69)

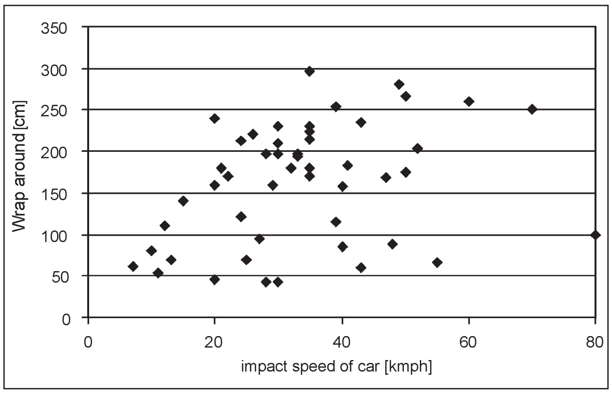

Figure 10: Impact speed and wrap-around distance (n=19)

3.5 Pedestrian

Pedestrian accidents could be sampled for PENDANT by groups in 6 countries which had at least some capability to conduct at-scene investigations. The database contains records for 69 pedestrians from 67 accidents.

Figure 8 shows the maximum injury severity for pedestrians. Approximately two-thirds were serious or fatal (MAIS 2+) casualties.

The walking direction of the pedestrian relative to the striking vehicle is represented in Figure 9. Half of the pedestrians (50.7%) approached the vehicle from its right-hand side. This means 'directly' from the kerb without reaching the centre of the road for most cases as the majority of the sample (67 pedestrians) are from countries where vehicles travel on the right-hand side of the road.

The wrap-around measurement is the distance around the contour of the car body from the road surface to the point of impact of the pedestrian's head Figure 10 shows that measurements approaching 300cm were observed and how these relate to the impact speed of the car.

3.6 Injury costing

A willingness-to-pay technique using a UK injury cost model was applied to the PENDANT database to attain an estimation of the cost of injuries. The method is described in detail in the final report of the project [2].

Figure 11 and Figure 12 provide a comparison of costs per body region for cars manufactured before and after 1998, based on the PENDANT sample for all crash types. The proportional cost of head injuries is highest in both groups at around 32-33%. This is followed by spine, thorax and lower extremity, in a slightly different order, for both newer and older cars.

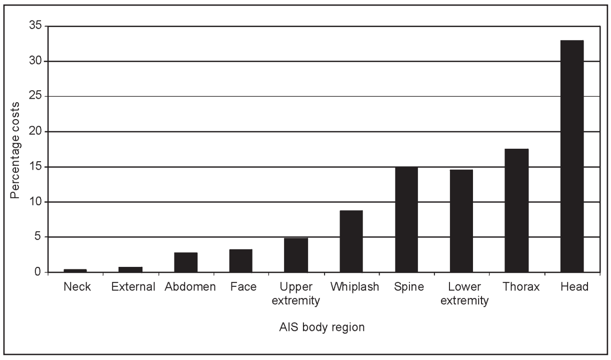

Figure 11: Cost of injury by body region for cars manufactured before 1998

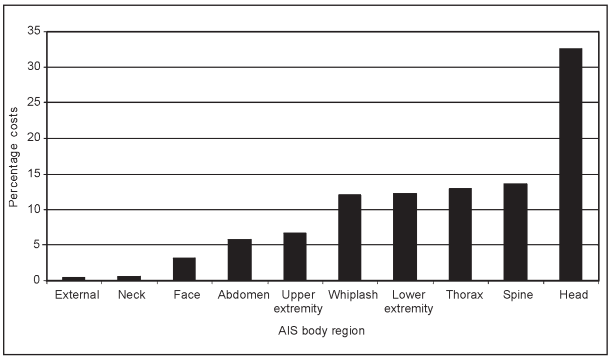

Figure 12: Cost of injury by body region for cars manufactured after 1998

3.7 EuroNCAP

One application of accident data is to develop and assess crash test conditions. The EuroNCAP frontal test uses 64km/h with 40% overlap between the barrier and front-end of the vehicle.

Figure 13 and Figure 14 show the distribution of Energy Equivalent Speed (EES) and overlap for vehicles in the sample that had frontal impacts. EES is a measure of the energy absorbed by a vehicle expressed as speed and is roughly comparable to the impact speed of a crash test

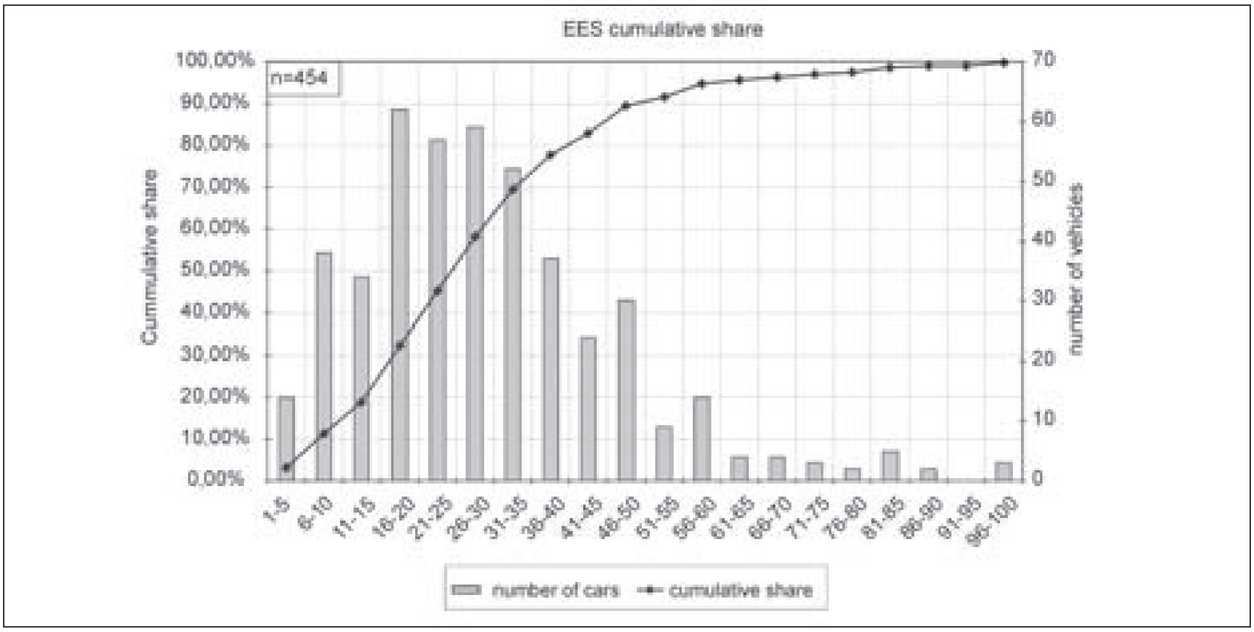

Figure 13: EES for vehicles in frontal impacts (n=454)

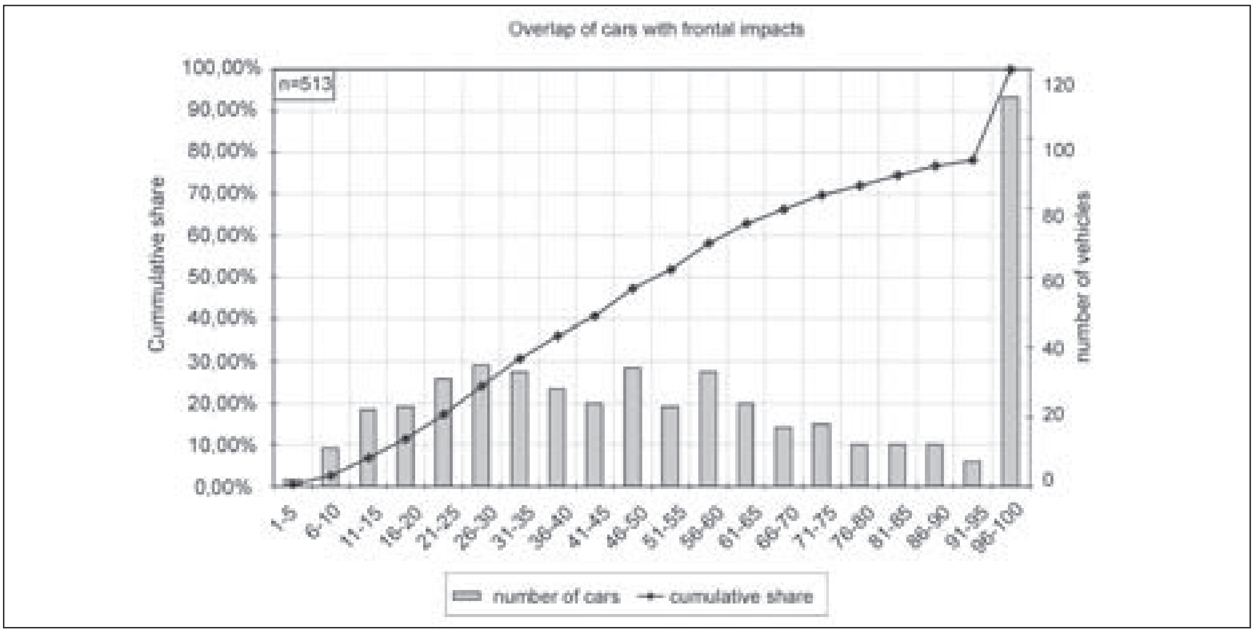

Figure 14: Overlap for vehicles in frontal impacts (n=513)

vehicle. It can be seen that 64km/h is around the 95-percentile level of impact severity and that there is a wide dispersion of overlap levels, with the EuroNCAP configuration (40%) lying in the central region of the range.

4 Discussion

The results presented in this paper are a small selection of those derived for the final report of the PENDANT project. They are intended to give an indication of the variety and interest of the study. The results touch on topical themes regarding front, rear, rollover and pedestrian accidents, injury costing, and comparison of real accident conditions to crash test configurations. Thus Figure 4 suggests improved crashworthiness in modern cars in frontal impacts; Figure 5 confirms the importance of whiplash in rear impacts, particularly among women; Figure 6 bears on the question whether rollovers without further impacts are benign events, while Figure 7 points to a possible beneficial influence of electronic stability control on rollover. The data on pedestrian impact speed and wrap-around distance in Figure 10 are relevant to current considerations on pedestrian test conditions and vehicle design. The application of an injury cost model to the PENDANT data in Section 3.6 suggests that head injuries remain a top priority in accidents involving modern cars. Finally, the results in Section 3.7 indicate that EuroNCAP frontal test is a severe test at 64km/h but appropriately configured at 40% overlap.

It must be stressed that the number of cases in the PENDANT database is too small to guarantee statistical representativeness within the European Union. With the expansion of the European Union from 15 to 25 members during the course of the study, it is clear that having 8 countries involved in Europe-wide data collection is sub-optimal. If PENDANT has demonstrated that the protocols for in-depth accident investigation developed in STAIRS can be implemented across Europe, a natural evolution would be to widen out to a expanded study across the EU-25, collecting baseline in-depth data through a routine operation to achieve full representativeness of the accident situation in the region.

The PENDANT project has raised many issues as potential priorities for European vehicle and road safety. These include:

- Further definition of injury mechanisms in front and side impacts, particularly for whiplash, chest injury and lower extremity injury.
- Evaluation of the effectiveness of advanced safety systems already installed, together with prediction of the effectiveness of emerging technologies.
- Consideration whether the priorities for secondary safety will remain as they are now as primary safety technologies penetrate the vehicle market.
- Further in-depth accident studies, including individual case reviews to fully evaluate the nature and source of injuries.
- A review of current accident studies to ensure that the methodology used in each allows satisfactory answers to outstanding research questions.
- Development of a rollover test including the potential to prevent ejection.
- Assessment of occupant protection systems in multiple impacts.
- Examination of the long-term consequences of crashes, injury costs and impairments.
- Evaluation of the potential for whiplash injury prevention from new seat design.
- Continued collection of enhanced data for accidents involving children with a view to the development of knowledge on child injury biomechanics.

5 Conclusion

The PENDANT study has demonstrated that the common protocols for collecting in-depth accident data originally developed in the STAIRS project can be implemented across Europe and that the results are useful to the development of EU vehicle and road safety policy. With the expansion of the EU to 25 countries, a natural evolution would be to instigate a routine data collection operation across a wider region, sampling sufficient cases to guarantee statistical representativeness.

A variety of issues have emerged as potential priorities for future research and action. The PENDANT database can support further extensive analysis than has been possible to date, and this would contribute further support to the formulation of European safety policy.

References

1 G. VALLET, B. LAUMON, J.L. MARTIN, P. LEJEUNE, P. THOMAS, R. ROSS, I. KOSSMANN, D. OTTE, B. SEXTON: STAIRS – Standardisation of Accident and Injury Registration, final report, Contract No RO-96-SC.204, February 1999

2 A. MORRIS et al.: PENDANT Work Package 2, final report, forthcoming (September 2006)