Final Project Report

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ACRONYM : PENDANT

TITLE : Pan-European Co-ordinated Accident and Injury Databases

PROJECT CO-ORDINATOR : Vehicle Safety Research Centre, Loughborough University UK

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Final Technical Report

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Executive Summary

The growing demand for greater mobility in European society has made individual transportation an essential feature of modern living. The motorised transport of people and goods has grown to such an extent that over 2,500 billion kilometres are covered every year by motor vehicles on European roads. In the twenty-five member states of the European Union, each year there are more than 50,000 people killed and 1.6 million injured, which represents an unacceptably high burden on Europe's society and economy. The impact of road accident casualties is a major public health problem for Europe.

The prevention of injuries by improved vehicle safety has been a central pillar in the overall casualty reduction strategy. The introduction of the front[1] and side[2] impact directives in 1996 accompanied by the EuroNCAP [3]Consumer information system was based on a systematic analysis of existing accident data that was used as the basis for the development of new test methods, which were the basis of subsequent test procedures. These policy initiatives have been the main driving factor in improving the levels of protection of cars and they demonstrated the value of sufficiently detailed accident data to support test procedure development. Nevertheless the accident data utilised had been gathered within special studies on a national basis and there was no uniform data available to describe the wider European accident population.

The EC funded Fourth Framework Programme STAIRS[4] project developed a standardised protocol to be used to gather in-depth accident data relating to the injuries of car occupants and pedestrians. It also generated guidelines on the statistical approaches required to develop a database that could be used to generalise to the EU. A conclusion of STAIRS was that the EC's 5th Framework programme could be used to implement the STAIRS protocols on a limited basis. This would include validation of the main recommendations and 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 a key part of the main PENDANT project.

The PENDANT project was implemented to resolve some of the key issues not addressed within STAIRS including methods to calculate collision severity, protocols to record the details of injuries sustained and the development of estimation methods to predict casualty reductions from new technologies.

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[1] EC Directive 96/79/EC Protection of occupants of motor vehicles in the event of a frontal impact and amendment of Directive 70/156/EEC

[2] EC Directive 96/27/EC Protection of occupants of motor vehicles in the event of a side impact and amendment of Directive 70/156/EEC

[3] www.euroncap.com

[4] Ross, R; Vallet, G and Otte D: STAIRS: Standardisation of accident and injury registration systems (1997). IRCOBI Sept 24-26th: Hanover, Germany.

The main achievements of the PENDANT project are listed below.

Methods to assess collision severity – A manual giving guidelines for accident reconstruction has been produced to serve as an overview of methods for crash analysts. A literature review of Crash-Data Recorders has assessed the capabilities of available systems to record information about the crash phase, including current and main obstacles to further implementation. A major output of this task was the development of the crash test database providing new access to EuroNCAP and other crash test data, which can be accessed at www.crashtestdb.com.

Traffic Users Injury Output Scales – a review of the available injury scales has identified that the Abbreviated Injury Scale is the most appropriate tool to describe the nature of injuries and measure threat to life. It also made recommendations for harmonised application to in-depth injury data and improved relevance to field data.

Predictive Methods for Estimating casualty and Injury Reductions – crash modelling methods were used to predict the change in crashes and injuries from the use of new technologies. PC-CRASH was used to estimate the changes in the nature and number of crashes if cars were equipped with electronic Stability Control while MADYMO was used to evaluate the reduction in injuries expected were cars to be equipped with certain advanced restraint systems.

Accident Investigation Infrastructure – a structure that can be used to investigate accidents in 8 countries has been established using specially trained teams in the UK, France, Germany, Netherlands, Finland, Austria and Spain and Sweden.

In-depth Accident Database – the teams have collectively investigated over 1100 crashes in-depth gathering extensive information about the nature of the collision, the vehicle damage, the performance of the safety systems and the injuries sustained.

Accident Data Analysis – the database has been analysed resulting in a report that reviews the accident situation and give guidelines regarding future priorities for injury prevention.

Linked hospital and police data systems – existing injury register databases in France, Netherlands and Spain have been reviewed for their purpose, data contents and the methods of linkage have been reviewed. Probabilistic, deterministic and manual methods are used.

Analysis of linked accident data – the data from the three countries, describing the injuries of nearly 100,000 casualties has been analysed to evaluate priorities in injury prevention and to identify issues related to under-reporting of crashes.

Objectives

The PENDANT project was established to develop a new level of crash-injury data on a European basis in a consistent manner that had not been done before. The overall objective was to establish a European level data infrastructure, which could be used to gather and analyse accident information at a greater level of detail than previously seen. The main objectives of the project can be summarised as follows:

1. A specification of core and add-on data elements covering both active and passive safety.
2. A new approach to estimate casualty reductions applicable to both primary and secondary safety countermeasures.
3. Harmonised procedures for assessing injury severity using threat to life measures.
4. A new in-depth crash injury database which, when analysed, will give results that can be used to form generalised conclusions about the European crash population. Data has been collected in eight countries to a uniform procedure and concerns injured car occupants or pedestrians.
5. Usage of hospital based data, linked or not with police and vehicle data, as a source of information on traffic safety, respectively on vehicle registration.
6. Analyses of both the in-depth database and hospital based data systems, to give feedback on effectiveness of existing countermeasures and priorities for future safety improvements.

As part of these objectives there was also the need to develop harmonised methods to evaluate collision severity in a way that could be implemented in a uniform manner by several investigating teams.

The incorporation of hospital register data and police level data enabled the group to demonstrate to what extent it is possible to analyse in a common way hospital data of road injuries to complement police data information coming from the three countries involved, despite all of their differences. The objective was to analyse the databases and identify priorities for future European regulatory and other action.

Development of accident investigation tools and procedures

The PENDANT project had the objective to define a set of accident investigation tools and procedures to be used to measure basic passive safety parameters including the severity of the collision in terms of the energy and momentum of the impact. A further task was to identify the injury severity scale that was most appropriate for European passive safety research and that recorded information both on the nature of the injuries and on the threat to life. A final objective was to investigate predictive methods that could be used with the accident data to estimate the likely outcomes had cars in the crash sample been equipped with active or passive safety technologies.

Accident Reconstruction and Collision Severity Assessment Guidelines

The STAIRS Project identified a lack of harmonisation over collision severity assessment as a major limitation regarding the comparison of crash test speeds with real crashes. The objective was to develop methods and guidelines for the reconstruction of road traffic accidents, which were initially designed for use by the different research groups who performed these types of reconstructions elsewhere in the project. A database was also developed containing the main information about available public domain crash tests (Euro-NCAP, etc.). Different reconstruction methods were investigated for determining the comparability and accuracy. The desired results of such a reconstruction are the determination of (pre-) crash speeds, the speed changes caused by the crash (Delta-v) and the energy dissipation from the deformation during the crash (EES, EBS) of all involved vehicles as well as avoidance considerations like avoidance speed, deceleration or reaction time. Specific reference was made to the use of smart technologies to collect and retain information about the crash (“Black boxes”, “crash recorders”). A review of the capabilities of such technologies was carried out and the main obstacles to their wider implementation were also identified.

Collision severity, as measured by “delta-V” “Energy Equivalent Speed” or “speed of impact”, is a fundamental parameter when describing impacts and injury outcomes. Crash test speeds are directly related to the collision severity in real-world serious or fatal collisions so it is important the severity measures are estimated using accurate and consistent methods. A variety of techniques used to estimate collision severity was assessed and it was decided to divide the task into three distinct parts:

(1) Reconstruction Guidelines,
(2) Crash-test Database and
(3) Crash-Recorders.

Reconstruction Guidelines

It was decided that the guidelines would be multi-dimensional and would involve a number of recommendations for both the PENDANT project and also for subsequent EC-supported projects involving accident reconstruction. It was therefore proposed that a booklet would be developed.

The following picture indicates several crash phases whereby two levels can be distinguished. The main focus was given to the crash phase and the factors necessary to perform accident reconstruction. More information on this subject can be found in the project deliverable “Accident Reconstruction Guidelines”.

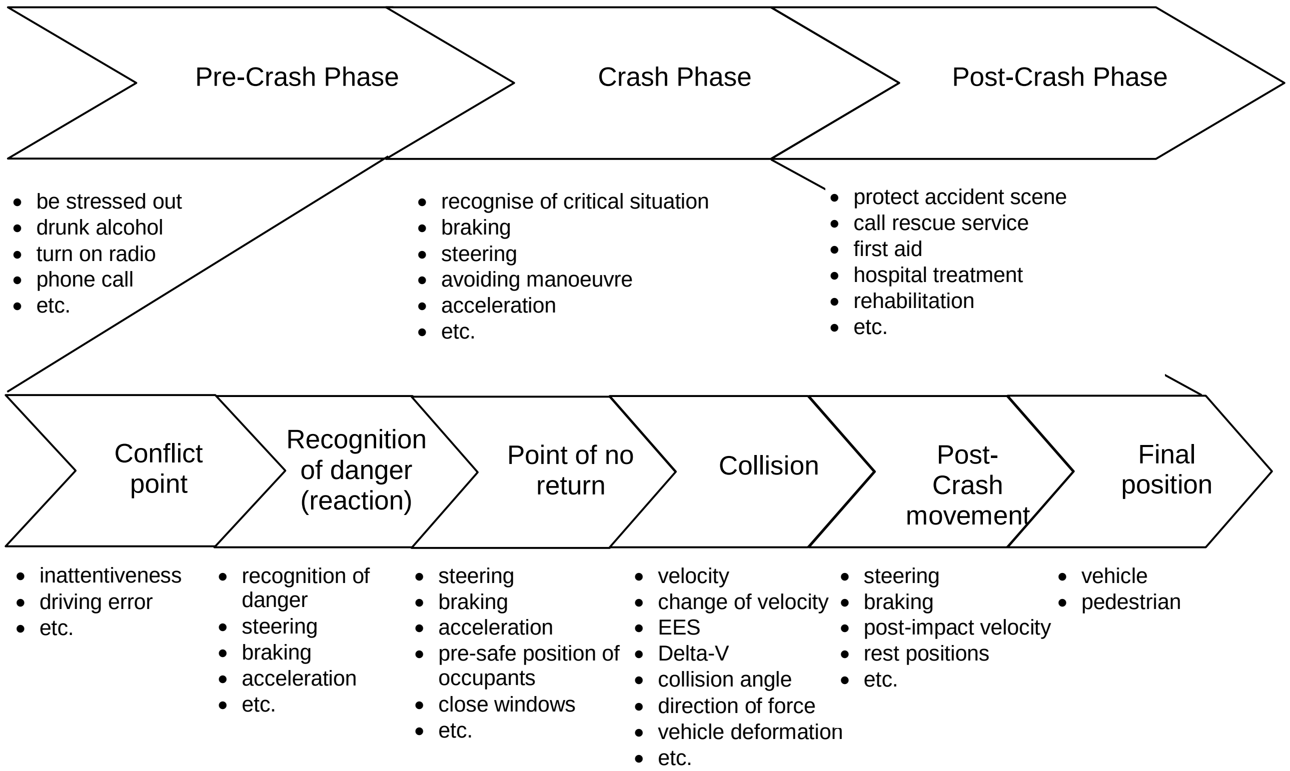


Figure 1 - Accident crash phases

The guidelines include the following:

- Techniques for measurement of deformations (CRASH3) and accident scene (measuring procedures, photogrammetry)
- Required equipment for reconstruction
- Enhanced Collision Deformation Characteristic (CDC) coding (using STAIRS approach)
- A description of existing reconstruction methods (including CARAT, MADYMO, PC-Crash, CRASH3 family, SMAC / ECSMAC, HVOSM / EDVSM, PHASE / EDVDS, AiDamage, Pedestrian throw)
- Evidence of accident scene and vehicle's interior and exterior (damage, material, wiping, casting, abrasion, melting marks, biological traces, webbing marks, throwing range of broken glass)
- A description of the main reconstruction parameters EES, ETS, Delta-V, EBS, BES
- Influence of road surface friction, tyres, etc.

Public domain crash-test database

The review of reconstruction methods revealed that one collision severity method used involved the comparison of the damage to a vehicle against similarly damaged cars from crash tests. With the crash test speed known it was therefore possible to estimate the equivalent speed of the accident vehicle. This method relied on the availability of a range of images and other information from crash tested cars and to facilitate this method the PENDANT team developed a new database of crash tests. The database would focus on data that was available from public crash-testing programmes such as EuroNCAP, US-NCAP, J-NCAP, Australia NCAP and ADAC. Not all of the results from EuroNCAP could be used as this would be too much for a database but this approach gave an additional benefit to EuroNCAP as previously no public database of any of the results had existed. The available data covered EuroNCAP phases 3 to 8 however once completed there was no capacity within the project to incorporate further releases of EuroNCAP data.

In addition to the data gathered from EuroNCAP, data from a series of rear end crash tests performed in Switzerland and Austria were also included (www.agu.ch).

The crash test database provides available information about vehicle(s) speed(s), acceleration characteristics of the vehicles/occupants, injury criteria and well-documented photographs for deformation assessment.

Following data and crash information is included in the database:

- standard information
- make
- model
- weight
- year
- well documented photographs for deformation assessment
- overview
- detailed picture of damage
- front (undamaged & damaged)
- side (undamaged & damaged)

- top view (undamaged & damaged, depicting final position)
- inside (pedal area, steering wheel, dash boards, etc)
- barrier
- crash severity data
- crash speed
- Δv
- EES
- deformation profile

EuroNCAP did not give approval for certain data to be added to the database including;

- barrier energy
- elastic energy
- video
- sensor records

The goal of the crash test database was to provide valuable information to the accident analyst, which will lead to a more accurate accident reconstruction. The crash-test database is in the public domain and therefore everyone can have access to the data. However the use of the data is limited to accident investigation/reconstruction or to scientific studies/projects.

It was decided that the site would be independent from institutes' internet sites. Reference to PENDANT and specifically to the database and can be found at www.crashtestdb.com.

The following diagrams outline the web pages used to access the data.

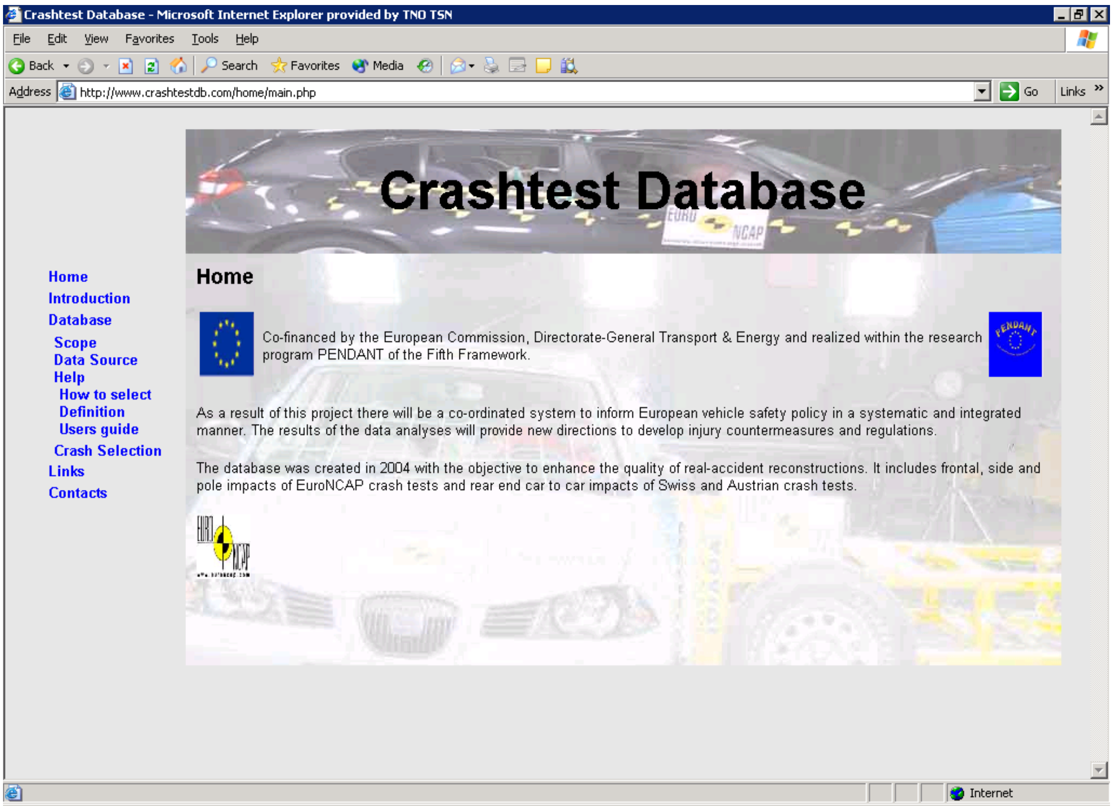
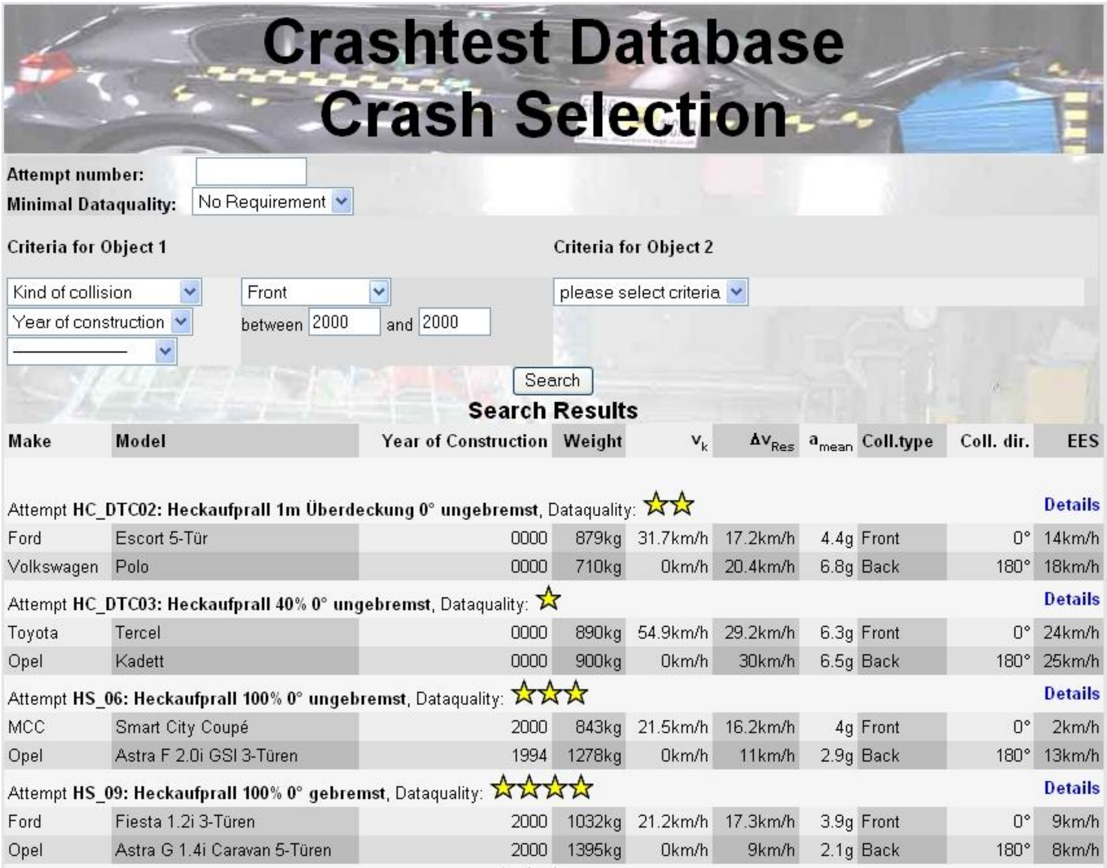


Figure 2 - Website of Crash-test Database



Make	Model	Year of Construction	Weight	v_k	Δv_{Res}	a_{mean}	Coll.type	Coll. dir.	EES
Attempt **HC_DTC02: Heckaufprall 1m Überdeckung 0° ungebremst**, Dataquality: ☆☆									**Details**
Ford	Escort 5-Tür	0000	879kg	31.7km/h	17.2km/h	4.4g	Front	0°	14km/h
Volkswagen	Polo	0000	710kg	0km/h	20.4km/h	6.8g	Back	180°	18km/h
Attempt **HC_DTC03: Heckaufprall 40% 0° ungebremst**, Dataquality: ☆									**Details**
Toyota	Tercel	0000	890kg	54.9km/h	29.2km/h	6.3g	Front	0°	24km/h
Opel	Kadett	0000	900kg	0km/h	30km/h	6.5g	Back	180°	25km/h
Attempt **HS_06: Heckaufprall 100% 0° ungebremst**, Dataquality: ☆☆☆									**Details**
MCC	Smart City Coupé	2000	843kg	21.5km/h	16.2km/h	4g	Front	0°	2km/h
Opel	Astra F 2.0i GSI 3-Türen	1994	1278kg	0km/h	11km/h	2.9g	Back	180°	13km/h
Attempt **HS_09: Heckaufprall 100% 0° gebremst**, Dataquality: ☆☆☆☆									**Details**
Ford	Fiesta 1.2i 3-Türen	2000	1032kg	21.2km/h	17.3km/h	3.9g	Front	0°	9km/h
Opel	Astra G 1.4i Caravan 5-Türen	2000	1395kg	0km/h	9km/h	2.1g	Back	180°	8km/h

Figure 3 - Database Crash Selection

Crash-Data Recorders

The purpose of this activity was to provide an overview of the state of the art in recording information about the crash phase, including current capabilities and main obstacles to further implementation. It was decided that this part of the task would examine the following issues:

- Definition and description of Crash-Data Recorders
- What is currently available
- Review of current literature
- What is/should be recorded? – current capabilities (ESP, ABS, OOP, occupant characteristics etc)
- Experience in US and Europe
- Liability and data protection issues
- Social implications (for example on driver behaviour)
- What can be used for research
- What should be recorded in the future
- Implementation
- Recommendations for future activity

In the absence of a legal requirement to install EDRs, the main impetus to wider implementation is likely to be the technical interests of the manufacturers themselves. The data recorded depends on manufacturer, the vehicle make, model and year.

The information available from the systems includes:

- date and time
- ignition on/off
- headlights on/off
- indicators on/off (left and right)
- siren on/off (if applicable)
- blue-lights on/off (if applicable)
- door contact
- seat belt use
- direction of travel (compass)
- brake application
- wheel speed
- longitudinal acceleration
- lateral acceleration
- yaw rate
- roll rate
- voltage supply to brake control module (BCM)
- anti-lock braking system (ABS) active/inactive
- electronic brake distribution (EBD) active/inactive
- stability control (SC) active/inactive
- traction control (TC) active/inactive

Some of the recorded information may be very useful for accident reconstruction and research for improved road safety. The crash phase is the main focus of secondary safety, where the some of the most important EDR data elements would be e.g. crash pulse (acceleration), change of velocity, airbag deployment, etc. Active safety research focuses more on the pre-crash phase, where events develop more slowly and relatively low-frequency recording would generally suffice.

Traffic Users Injury Output Scales

Measurements of injury outcome were the second set of fundamental crash parameters accompanying collision severity estimates. This task addressed the accepted injury scale measuring threat to life (Abbreviated Injury Scale) and made recommendations for harmonised application to in-depth injury data and improved relevance to field data.

The objectives of this task was to develop a harmonised method of coding injuries and resulting residual impairments across Europe taking account of the requirements for field data use. Overall there are few coding systems in existence on a worldwide scale that are well known and used on a daily basis to code injuries. The AIS is one of the only coding systems that actually describe injury by severity. The methods used included a review of injury coding methods, identification of the limits of the available scales, identification of areas of divergence.

Injuries are coded for a number of research purposes; for example, the use of codes enables injury data to be used in statistical analyses for comparative purposes and to study predictive outcomes such as mortality in vehicle safety engineering research. Within the clinical field, injury data is also used for survival analysis and for the compilation of national statistics.

Numerous scales have been considered and appraised for the purposes of injury scaling and coding for the PENDANT project. An immediate recommendation was that the most appropriate scale for the project involves whole-body injury descriptors because of the diverse nature in the pattern of injuries amongst crash victims. Other Scales that have been reviewed as part of the PENDANT project do have their merits and could be used on a needs-basis if a requirement for special injury outcomes becomes evident as a subsidiary element of the main PENDANT study. Injury scales that deal with single body regions, (such as Glasgow Coma Scale, Organ Injury Scale) have limited applicability, are more suited to more specialised research projects.

Garthe et al[5] observed that injury scales fall within one of five types:

- Severity with focus on location of injury (US National Automotive Sampling System - NASS)
- Severity with focus on identification of injury (Abbreviated Injury Scale - AIS)
- Classification with primary use in mortality (International Classification of Diseases - ICD)
- Modified classification with primary use in reimbursement (ICD-CM)*
- Impairment with focus on identification of injury (Functional Capacity Index - FCI).

**developed form the ICD-9 and used in North America for reimbursement of Medicare*

An assessment of the nature and threat to life from specific injuries provides fundamental data for crash injury research. Several Injury Scales are available to be used for crash injury research but each has its own limitations and opportunities.

In the absence of an 'ideal scale', (which according to Garthe et al[6] would be a unified injury scale incorporating the needs of engineers and clinicians), it was recommended that the PENDANT project utilises the injury scale that was most relevant and can be most easily used by all partners. The chosen scale had to incorporate detailed injury descriptions, injury location and severity. It was found that only two Scales allowed the degree of required information to be handled in an appropriate and simplistic manner, namely the Abbreviated Injury Scale (AIS) and the International Classification of Diseases (ICD) Scale.

When consideration is made of the available 'general' injury scales for the PENDANT project, it is evident that the AIS scale has been used in vehicle safety research since its conception in the 1960's. The scale has the ability to be adapted meaningfully to calculate any benefits from introduction of safety countermeasures such as, for

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[5] Garthe E, States J D, mango N K (1999)

Abbreviated Injury Scale Unification: The case for a unified injury system for global use. Journal of Trauma 47:2 309-323

[6] Garthe E, States J D, mango N K (1999). Abbreviated Injury Scale Unification: The case for a unified injury system for global use.
Journal of Trauma 47:2 309-323

example, seatbelt and airbags in passenger vehicles. The ongoing revisions of the AIS system has ensured that changes in injury severity have been updated as medical procedures and hence survivability has improved over time. The proposed new version of the AIS dictionary has furthered the ability to code injuries at a more complex level and is expected to include ‘injury aspect’ as an additional factor within the code. This new version requires obtaining detailed injury information. As with any use of the AIS system there was a requirement that all coders undertake the necessary training in its use, which was a consideration.

The ease of using existing hospital information data such as ICD10 for PENDANT relies on a number of assumptions, chiefly that individual codes could be obtained for all persons involved in the study, that all Countries are using the same ICD versions which should be ICD10, and that severity is not an important issue within the study. A facility does exist to convert ICD9 codes to AIS codes to determine severity and also calculate ISS; however this ‘mapping’ of databases is only suitable for mass databases. PENDANT with approximately 1,100, probably does not qualify as a mass database (Mackenzie et al 1989[7]). Presently, such mapping of databases has only been updated for the ICD9 and AIS90 versions and was not available for ICD10.

A further consideration was the special development of a Scale specifically geared towards the needs of the PENDANT project but this would have required a significant investment of project resources. Given that at this stage only some 1,100-accident investigations were proposed, such a level of investment would have not been the best use of such resources.

Whilst neither the AIS nor the ICD Scale comprehensively addressed the needs of the project, it was proposed that the Abbreviated Injury Scale 1998 revision should be used subject to the following provisos:

- That all PENDANT partners undertake an introductory training session on the appropriate use of the AIS98 Injury Scale;
- That where appropriate, the Injury Severity Score (ISS) and the Maximum Abbreviated Injury Scale (MAIS), which originate from the AIS code are used in conjunction;
- That quality control measures are imposed within the PENDANT data management system to ensure quality and consistency of data;
- That the PENDANT project maintains a direct dialogue with the European Injury Scaling Committee with regard to current development of a revised version of the Abbreviated Injury Scale.

Additional AIS was originally designed for use by non-clinicians however a basic knowledge of anatomy is required to be able to apply codes. Sometimes, clinical

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[7] Mackenzie E J, Steinwachs D M, Shankar B S (1989) Classifying severity of trauma based on hospital discharge diagnosis: validity of a ICD-9CM to AIS-85 conversion table.
Medical Care 27: 412-422

knowledge is needed to interpret the injuries. The AIS forms the basis of a number of other scores from which data can be presented in a more useable format particularly in vehicle safety research. It also forms the basis of some 'overall' severity scores that are used to predict the probability of survival from the injuries sustained and also has the ability to be included within costing calculations of road trauma. The measures are the Maximum Abbreviated Injury Score (MAIS) and the Injury Severity Score (ISS).

Predictive Methods for Estimating Casualty and Injury Reductions

This task focused on methods to estimate the likely casualty reduction possibilities of safety strategies so that the value of different countermeasures can be compared. In a first step a statistical analysis was performed to compare the casualty of single accidents of cars with and without Electronic Stability Programme (ESP). In a second step the most well documented 20 (if available) single car accidents with cars not equipped with ESP was identified by the first analyses from the in-depth database collection in WP2. These accidents were additionally investigated and reconstructed. In comparison each case was simulated with the assumption that the cars were equipped with ESP. The differences regarding accident avoidance or severity as well as reduction of injury risk was investigated and the effectiveness documented.

The influence of engineering countermeasures were also investigated using a general simplified multi-body car model for the collision phase which will be used to predict the acceleration, deformation and intrusion behaviour of the involved cars during a real world accident. The validation of these models is based on available crash test data of comparable EuroNCAP tests found in the database developed in task 1.1. The validated model was used to simulate a real world accident and predict the injuries and/or the effect of engineering countermeasures like improved restraint systems on the injury risk of the occupants.

Accident countermeasures

ESP

A literature review was performed which included the following items:

- How did ESP systems evolve
- What are they designed to do
- What technology is involved
- How widespread have they been implemented
- How are future systems likely to evolve
- What do initial field studies tell us about effectiveness

After analysing the database and filtering all single vehicle accidents approximately 200 cases were found which corresponded to CARE Plus group C. In more detail CARE Plus subgroup C11 (Single vehicle accident - leaving straight road - either side of the road) and C13 (Single vehicle accidents in a bend - going either side of the road) were taken into account. It was agreed to use the reconstruction software PC Crash for this purpose. Unfortunately as the PENDANT project was more or less focussed on passive safety rather than active safety and only a small number of partners were investigating accidents on-scene, in-depth on-scene accident sketches with road width or lengths of skid marks (skidding, braking, etc.) and other evidences including pictures from accident scene were rare. Without that information it is impossible to reconstruct accidents which should reflect an active on-board system. Finally only 14 cases could be filtered which met all criterions (mainly from Austria, Germany, Netherlands and Sweden). To achieve the goal of at least 20 cases an additional database was taken into account too. The database ZEDATU (Zentrale Datenbank tödlicher Unfälle in Österreich mit Auswertung der Vermeidbarkeitsmöglichkeiten) of TU Graz was studied where all fatalities in Austria from 2003 were stored. The database is based on STAIRS protocol and enhanced by several European projects which were investigating in-depth accidents.

The accidents caused by a chain of circumstances were categorized on the basis of on-scene material and regarding street section into bends or straight roads. It was seen that within the analysed cases the driver tried to avoid an accident and counter steered n-times. In many cases the vehicle started skidding and no intervention by the driver could stabilise the car.

In most of the cases the accident was initiated by an emergency manoeuvre of the driver (pulling the steering wheel) due to previous inattention. The driver tried to avoid leaving the road to the side or a collision with an obstacle on the road.

In principle four manoeuvres were found for bends and on straight road sections:

- Skidding
- Counter steer 1x
- Counter steer 2x
- Counter steer 3x

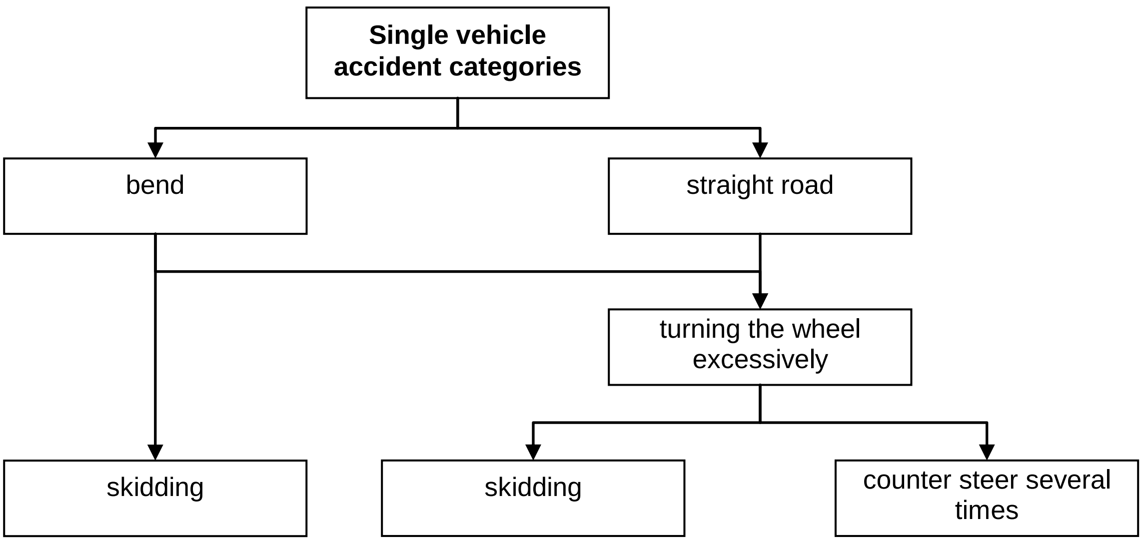
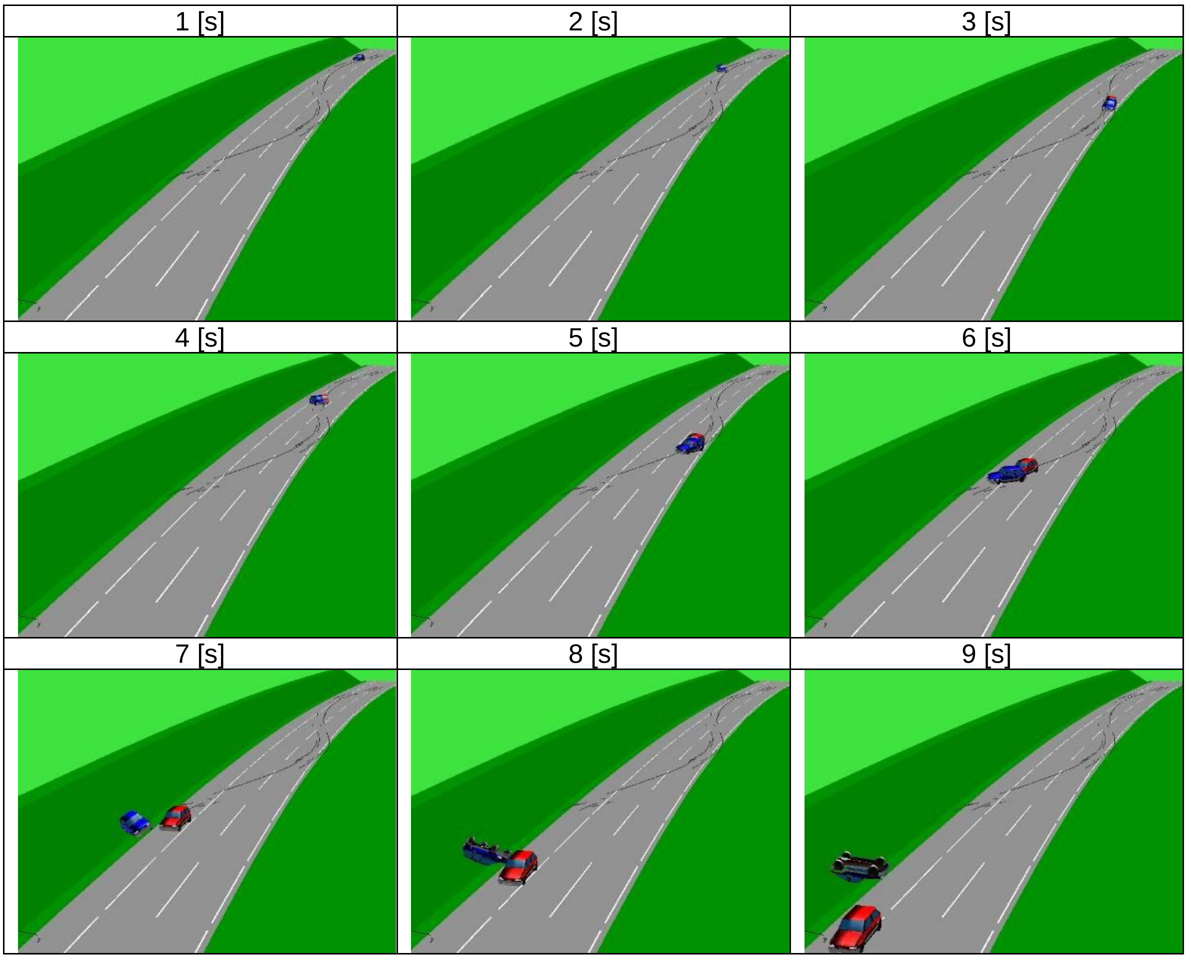


Figure 4 - Single vehicle accident categories

The picture below gives an overview of a single vehicle accident whereby the blue car did not have ESP on board and the red car did.



Subsequent table gives an idea of the number of cases with the steering behaviour of the drivers.

Table 1 - Accident sequences

	pull steering wheel	skidding	counter steer 3x	counter steer 2x	counter steer 1x	
bend	no	4			1	5
	yes	4	1		3	8
bend result		8	1		4	13
straight road	no	1				1
	yes	5	1	1	5	12
straight road result		6	1	1	5	13
		14	2	1	9	26

Emergency manoeuvres were caused due to inattention the vehicle went to the verge and the driver tried to alter the course. The driver pulled the steering wheel and had to counter steer to avoid leaving the road offside or started skidding and lost control completely.

Due to bends in the road and high speed the vehicle started skidding and the driver lost control and finally hit a tree or post or even resulted in a rollover.

In five cases the driver could counter steer but resulted in an accident anyway. For accidents on straight sections obstacles on the road and inattentiveness of the drivers were responsible for emergency manoeuvres. In seven cases it was possible to counter steer. If the vehicle started to skid no intervention from driver was possible anymore.

For accidents which couldn't be prevented ESP led at least to another impact configuration:

a) Sliding
Accident couldn't be avoided and sliding still occurred

b) Leading to slight impact
This might be a frontal collision with a low Delta-V or a sliding collision with a road side barrier or a tree/pole/post.

c) Leading to frontal collision
For accidents where drivers tried to prevent the accident and had to counter steer - resulted in side impacts with road side barriers or trees/poles/posts. ESP didn't prevent the accident but led to a frontal collision.

d) Other
This category is for those accidents which couldn't be coded with the other three types.

Following abbreviations were used in the next two tables:

n/a not applicable

ai after impact

bi before impact

ni no impact

The next two tables provide an impression of certain parameters of reconstructed single vehicle accidents. The first table shows the cases which could be prevented by ESP. The second table shows those accidents which were not avoided or led to different impact configuration respectively.

Table 2

without ESP						with ESP			
impact location	**PDoF**	**speed limit**	**Rollover**	**Delta–V [kph]**	**occurred**	**impact location**	**PDoF**	**Delta –V [kph]**	**Rollover**
F	01	120	no	51	n/a	Prevented by ESP			
L	10	50	yes	22	ai				
L	11	70	no	8	n/a				
L	02	100	no	55	n/a				
R	11	80	yes	7	ai				

R	08	100	no	32	n/a	
T	00	100	yes	n/a	ni	
T	00	130	yes	n/a	ni	
k						

Table 3

without ESP						with ESP			
impact location	**PDoF**	**speed limit [kph]**	**Rollover**	**Delta -V [kph]**	**occurred**	**impact location**	**PDoF**	**Delta -V [kph]**	**Rollover**
F	01	50	no	11	n/a	R	02	5	no
F	01	70	yes	44	ai	L	11	15	no
F	11	130	no	27	n/a	L	10	9	no
F	01	130	no	40	n/a	L	09	4	no
L	08	70	yes	20	ai	F	12	52	no
L	10	100	no	37	n/a	L	10	4	no
L	08	130	no	74	n/a	L	08	64	no
L	11	999	no	58	n/a	L	10	8	no
R	02	50	no	29	n/a	R	01	8	no
R	02	70	no	49	n/a	F	01	70	no
R	12	80	no	49	n/a	F	12	70	no
R	02	100	no	57	n/a	F	01	67	no
R	01	100	no	66	n/a	R	02	5	no
R	08	100	no	66	n/a	R	02	6	no
R	07	999	no	39	n/a	F	01	23	no
T	03	50	yes	20	bi	F	12	50	no
T	00	70	yes	n/a	ni	M	00	n/a	yes
T	00	100	yes	n/a	ni	M	00	n/a	yes

Even though the PENDANT database was focused primarily on passive (or, secondary) safety issues an attempt was made to evaluate the effectiveness of active (or, primary) safety systems, namely Electronic Stability Control Systems.

Apart from certain data quality issues, somewhat predictably difficulties were encountered with availability of required information, for example exposure. Such difficulties are not unique to PENDANT, and these problems can be counteracted by using pre-existing data such as induced exposure methods. However these methods require information on the role of vehicles in the accident (at fault or random opponent), which is not available in PENDANT. This is also true for any kind of pre-crash data - initial speed, longitudinal and lateral acceleration, yaw, braking or steering input, trajectory, etc. Another difficulty is PENDANT's bias with respect to the vehicle fleet which makes any projection of results to a national or EU level highly problematic.

Investigation of single vehicle accidents in a more detailed way determined that vehicles which were equipped with ESP reduced single vehicle accidents by approximately 30%. Due to the low number of accidents a statistical estimation of accident reduction was not possible and not representative but PENDANT and

ZEDATU single vehicle accident sample shows a good correlation with previous studies anyway.

In many cases the impact configuration would have been changed. Side impacts led to frontal impacts. Depending on the road side infrastructure it could lead to a minor severe accident or in a few cases even to a more severe one. An estimation of MAIS from Delta-V could be possible if enough cases can be analysed but there are still severe injuries for low Delta-V. Therefore the whole accident situation has to be analysed and impact configuration needs to be analysed as well. Age and constitution of the occupants are other important considerations.

Even if ESP could prevent or lead at least to minor accidents the road side infrastructure needs to be investigated. In many cases trees or poles/posts are too close to the road and not enough safety zone is left. Additionally drivers try to avoid collisions with trees even if it would be better to leave the road. Due to emergency manoeuvres the vehicles started to skid and mostly this resulted in side impacts or rollovers. Vehicles got into trouble when they skidded sideways and the wheels got stuck in the soil.

Improved restraint systems

The strategy of the effect of improved restraint systems on the injury of occupants was defined as follows:

- Selection of two VC-Compat/PRISON multi-body vehicle crash models which represent the majority of the passenger car population;
- Selection of real accidents between two cars from the PENDANT accident database with conditions comparable to the EuroNCAP frontal impact tests and both cars involved are tested by EuroNCAP;
- Selection of one real accident case in which both vehicles are represented by a different vehicle crash model;
- Validation of the two vehicle crash models with EuroNCAP frontal impact test data;
- Simulation of the real accident with both vehicle crash models using the EuroNCAP parameter values and prediction of the injuries of the occupants;
- Comparison of the injuries of the occupants with the real world accident;
- Determination of the effect of improved restraint systems on the injuries of the occupants with new simulations;
- Findings.

For the benefit assessment of improved restraint systems two generic MADYMO vehicle crash models for car-car frontal accidents were chosen on basis of their vehicle mass:

- Chrysler Neon with an original mass of 1371 kg;
- Geo Metro with an original mass of 1191 kg.

These vehicle models were validated with EuroNCAP frontal impact test data of the cars involved in a real accident. For the validation of the vehicle models the displacement of the B-pillar among others shall be used. The B-pillar displacement is not measured in the EuroNCAP frontal tests, but can be constructed from the B-pillar acceleration. For the oldest EuroNCAP cars, this acceleration is not always present in the signal list and those cars shall be omitted in the selection.

The PENDANT database was used as a data source to select frontal car-car accident cases and from this selection only those cases were chosen in which both cars had been tested by EuroNCAP and the necessary signals were available in the EuroNCAP frontal test data.

From the selected accident cases the following information was gathered:

General vehicle data

- Model
- Make
- Variant
- Year
- Kerb weight
- Weight at crash.

Crash data

- Delta-V
- EES
- ETS
- Offset
- CDC1 – CDC8.

Occupant data

- Age
- Gender
- Height
- Weight
- Seat and row position
- PENDANT severity level
- Presence and use of restraint system(s)
- Presence and use of airbag(s)

At this point the PENDANT database contained a total of 958 accident cases consisting of 40 cases (4.2%) with frontal car-car crash accidents. Combining the selection with the EuroNCAP vehicle list gave eight accident cases with 16 cars and 31 occupants. It is remarkable that no very new cars were involved in the selected accident cases, the year of manufacture ranged from 1996 to 2002. The final accident case was chosen from the selected eight cases with the extra condition that both cars were represented by a different vehicle crash model.

Based on the existing Madymo Multi Body vehicle models, two generic vehicle models were selected and validated with the corresponding EuroNCAP test data. As an improvement to the restraint system a pre-crash pretensioning of the safety belt of the driver of the NEON (figure below) simulation model was applied. The real accident was simulated again, but now with this pre-crash pretensioning system. The results were compared to the results without pretensioning.

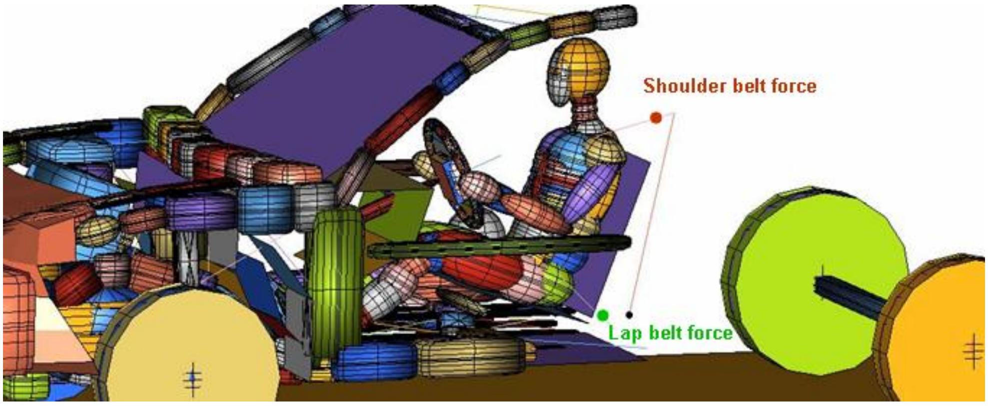


Figure 5 - Bullet car (NEON) Belt forces measurement

The results of this investigation indicated that pre-crash pretensioning has a beneficial effect on the driver response, providing lower loads during the crash event and thus resulting in lower levels of injuries. This can be explained by the fact that, as a result of pretensioning, the driver is pushed backwards in the seat thus gaining additional space for energy absorption and dissipation during the crash.

In general it can be concluded from this investigation that generic vehicle crash models, which are validated with crash test data, can be used to predict injuries of the occupants and also the effects of improved restraint systems.

Comparison of planned activities and actual work accomplished

Accident Reconstruction and Collision Severity Assessment Guidelines

It was very difficult to gain access to EuroNCAP data and then to gain permission from the EuroNCAP team to develop a public domain database. Additionally due to the difficulties of obtaining the source codes from the developer of the AGU database, deliverable D4 was not completed on time and the date for the deliverable had to be revised. Furthermore TNO slightly modified the AGU database and started filling in some test data. There was also a huge amount of information available for each EuroNCAP test with total contents extending to 70 CD-ROMs, so compiling these data was more time consuming than anticipated.

Originally deliverable D4 was scheduled for month 13 but was finally completed in month 29.

Traffic Users Injury Output Scales

No major difficulties were encountered during the undertaking of deliverable D1 apart from the fact that some of the injury scales that needed to be reviewed were a little problematic to track down. The level of detail that was required to undertake the task was somewhat demanding but the overall objective was attained.

Predictive Methods for Estimating Casualty and Injury Reductions

Due to the postponement of deliverable D4, the work for the deliverable D8 started later than scheduled. Additionally as the project progressed, it became clear that some of the teams involved in the gathering of accident data would be unable to fulfil data collection in-time and therefore there were insufficient accident cases available to cover the requirements for the task “Predictive methods for estimating casualty and injury reductions”. An application for an extension of the Deliverable date for D8 (to M42) was made. Difficulties were found for accident reconstruction activities due to the absence of on-scene material. PENDANT was designed to focus on passive safety rather than on active safety. For pre-crash investigation on-scene material is essential and it was noticed that some of partners gathered this information even if it wasn’t necessary for PENDANT.

The following issues further delayed the progress of the deliverable:

- The first analysis of the combined PENDANT database delivered only a few accident scenarios. A second analysis of a later updated version of the database had to be performed in order to have a larger number of frontal collisions available for the computer simulations.
- Not all sensor signals of the b-pillar of the selected EuroNCAP vehicles were available for analysis. TNO requested access to this data.

State of the art review

The Accident Reconstruction Guidelines were designed in the first instance to support the data collection activity within the project. The guidelines are also designed to support novices in accident reconstruction. The purpose of the investigation of Crash-Data Recorders was to provide an overview of the state of the art review in recording information about the crash phase, including current capabilities and main obstacles to further implementation. As a major output of this task the development of the EuroNCAP database can be seen. At this point no public EuroNCAP crash test database was available nor was it at the EuroNCAP consortium. All test results were stored on CD ROMs.

The Traffic Users Injury Output Scales addressed the accepted injury scale measuring threat to life (Abbreviated Injury Scale) and made recommendations for harmonised application to in-depth injury data and improved relevance to field data.

While one part of *Predictive methods for estimating casualty and injury reductions* was to focus on active safety another was to focus on engineering countermeasures on passive safety. As an active safety aspect single vehicle accidents using vehicles not equipped with ESP were reconstructed. These single vehicle accidents were then reconstructed with the assumption that the vehicles were equipped with ESP. The results were compared and documented.

The passive safety part was to use a general simplified multi-body car model for the collision phase. The influence of different engineering countermeasures was investigated and injury risk and effectiveness has been analysed.

Crash Injury Database

The principle scientific objectives of this task are to develop a set of crash and injury data systems that are co-ordinated with the CARE database. This co-ordination means the new data will be linked statistically and conceptually so that together they will give a comprehensive view of injury causation to all road users but with maximum detail for the largest groups most closely under the competency areas of the Commission.

The in-depth data will adopt a standardised, targeted approach towards the newer accident involved cars so that the data is most efficiently directed towards new strategies for car occupants and to some degree, pedestrian safety.

The objectives of this task can be summarised as follows;

To further enhance the STAIRS methodology and develop a dictionary of data fields for both passive and active safety;

- To develop a system to investigate the causes of injuries based on the STAIRS methodology in eight countries;
- To develop a standardised, demonstration database system to facilitate data entry and combined analysis;
- To investigate at least 1100 accidents involving injured car occupants and pedestrians and compile the data into the database;
- To analyse the composite database and identify priorities for future European regulatory and other action.

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 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. However, there is 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[8] a single European-wide crash injury database would be of exceptional benefit to the legislation process at EU level. A direct data-driven approach would allow identification of any safety problems at an early stage and

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[8] Ross, R; Vallet, G and Otte D: STAIRS: Standardisation of accident and injury registration systems (1997). IRCOBI Sept 24-26th: Hanover, Germany.

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 (although not specific) investigative approach.

At the conclusion of the STAIRS project, the EC stated that there was general support in principle for the implementation of the STAIRS recommendations, albeit with certain barriers that needed to be overcome. However, 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 and 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 a task of the main PENDANT project.

The aim of the task 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 to inform 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.

The main activities were based around the data collection and database construction activity and contained the supporting tasks necessary to ensure that data was consistent and validated to the levels specified in the STAIRS final report.

It was the intention that the level of detail recorded for each case would be considerable - the STAIRS protocol specified 400 variables covering accident, vehicle, casualty and injury attributes. It was proposed that these would be included in the dataset together with the relevant CAREplus fields for each crash so the resulting database would have a substantially greater level of detail than CARE. However, where possible, the common data element definitions used in CARE would be used in the data elements of the PENDANT database.

At the outset of the project development, the EC comprised 15 Member States. Therefore at this time, the groups collecting the crash injury data covered the northern, middle and southern EU to give a representative range of accident conditions. It was intended that a special feature of the data would be the case selection methodology which would be targeted to cover newer vehicles to give data that has most value for regulation and safety countermeasures, unlike most other systems.

It was proposed that the partnership would include many of the European groups with experience in real-world accident research and also those groups with experience in systematic studies of a more local scale. For example, the VSRC (the task Leaders) is a University research organisation that has investigated over 10,000 accidents since 1983 using either in-depth retrospective or on-the spot methods. INRETS has conducted similar studies in France and has also developed a major French hospital injury database. MUH in Germany has experience of investigating around 9,000 accidents in-depth since 1985. These three partners were also members of the STAIRS project which conducted much of the protocol development to be used in the PENDANT project. Together the Partnership provides the wide ranging, multidisciplinary range of skills required for the project.

Table 4 – PENDANT partners involved in data collection activity

Partner	EU Member State	Partner Activity	Role in Work Package 2
VSRC	UK	University research centre in the field of accident investigations and data application to policy	Project Co-ordinator, leader WP 2 In-depth crash injury data, injury scaling, crash reconstructions
INRETS	FR	Research organisation in the field of ‘accidentology’ and road accident epidemiology	In-depth crash injury data collection
ARVAC	FR	Organisation dedicated to injury data collection	Medical data collection and injury analysis
MUH	DE	University research centre in the field of accident investigations	In-depth crash injury data collection
TNO	NL	Research Group in field of crash modelling, dummy development and crash testing	Crash reconstruction, in-depth crash injury data collection
TUG	AT	University group in field of pedestrian and car occupant safety	In-depth crash injury data collection/database development and management, website development
CETE-SO	FR	Responsible for CAREplus programme	Link to CARE/statistical support
Chalmers University	SE	University Research group in field of biomechanics and injury prevention	In-depth crash injury data collection
UPM - INSIA	ES	Research group in field of automotive safety	In-depth depth crash injury data collection
Turku	FIN	University group conducting real-world accident research	Collection of in-depth crash injury data
SWOV	NL	Research organisation in field of traffic safety	Participation of in-depth crash injury data

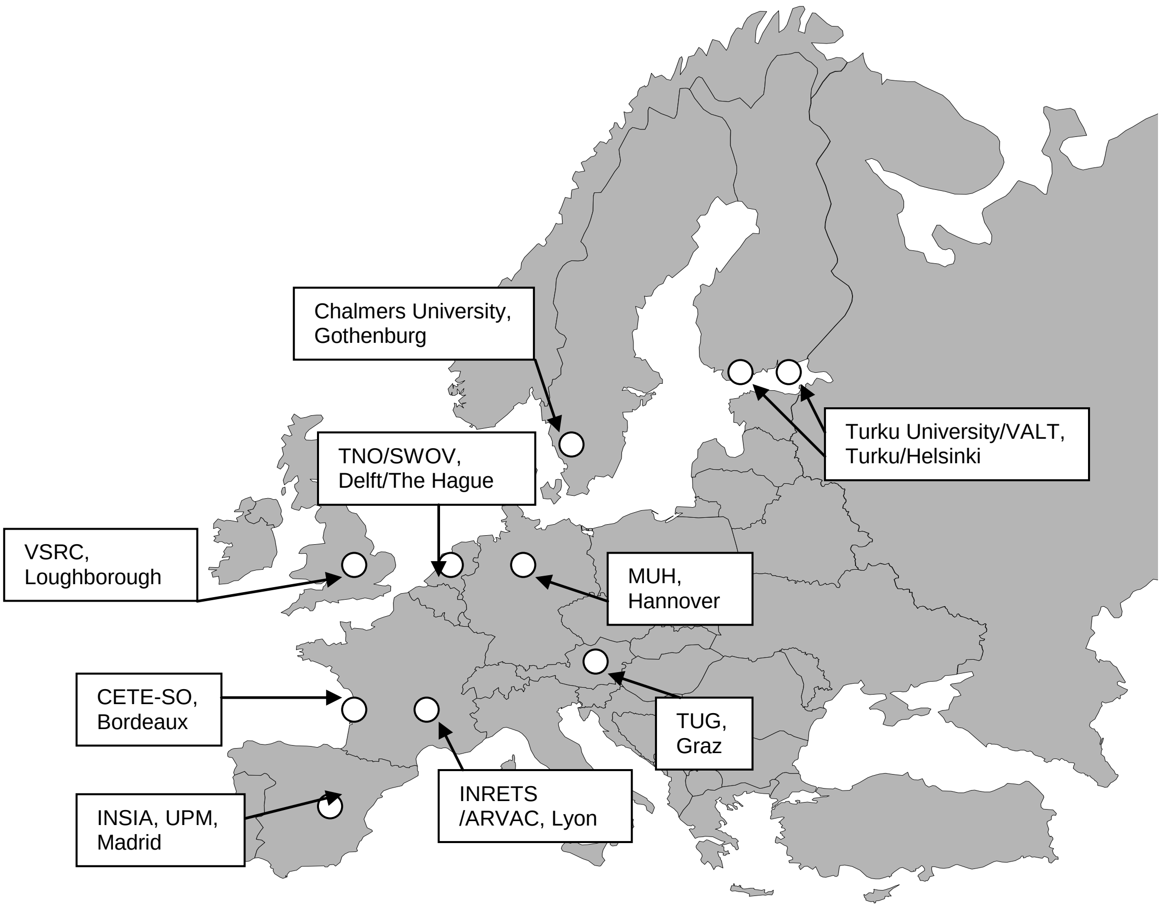


Figure 6 - Data Collection Centres in PENDANT

The creation of the Crash Injury Database was divided into 5 distinct tasks. These are described below.

Data Systems

The STAIRS data specification was to be reviewed to take account of changes in safety technology that have taken place since the STAIRS protocol was finalised. It was also to be revised to include the data fields specified since STAIRS completion by the CAREplus project so as to direct comparability of data and to support the STAIRS methodology.

The STAIRS protocol only addressed the data needs for crashworthiness; however, since its completion the need for accident causation data increased. This task was designed to review the protocols used in national and other projects (e.g. European Accident Causation Study, Motorcycle Accident In-depth Study, UK On-Spot protocol, Hanover University etc) to develop a new protocol based on “best practice”.

Training and support for data collection teams

Each team collecting data required initial site training to the STAIRS/PENDANT protocol to ensure that the data was consistently collected between teams. Preparation and presentation of the training material was to be conducted by the Partners with considerable crash investigation experience (VSRC, INRETS, and TUG). It was intended that a workshop would be held whereby the training course would be presented. It was decided that once the protocol was operative, there was a need to confirm that the full methodology; including data quality control, confidentiality and ethics procedures as well as data accuracy was being adhered to. Therefore, ongoing support was provided regarding the coding of information into the database so as to ensure that the conditions for fully harmonised data collection and exchange were met. This was also supported by annual project workshops. It was the intention that these workshops would involve partner case reviews and clarification of the data coding protocols where required.

Data Collection

The overall aim of data collection was that each group would build a system that would eventually result in the investigation of at least 50 cases each year but it was recognised that some groups would use the first year as a pilot, achieving full capacity only in subsequent years. The numbers of cases committed by each team were as shown in the following table;

Table 5 – PENDANT case load

Team	Year 1 case numbers	Year 2 case numbers	Total
VSRC	100	100	200
INRETS	50	75	125
MUH	75	75	150
TNO/SWOV	90	90	180
TUG	25	50	75
CTH	50	100	150
UPM - INSIA	63	63	126
Turku/VALT	40	40	80
Total	**493**	**593**	**1086**

Each team was expected to collect the same data using the same selection criteria and protocols. It was planned that data would be fully compatible with the STAIRS protocols although it was recognised that the precise data collection methods could vary according to local requirements.

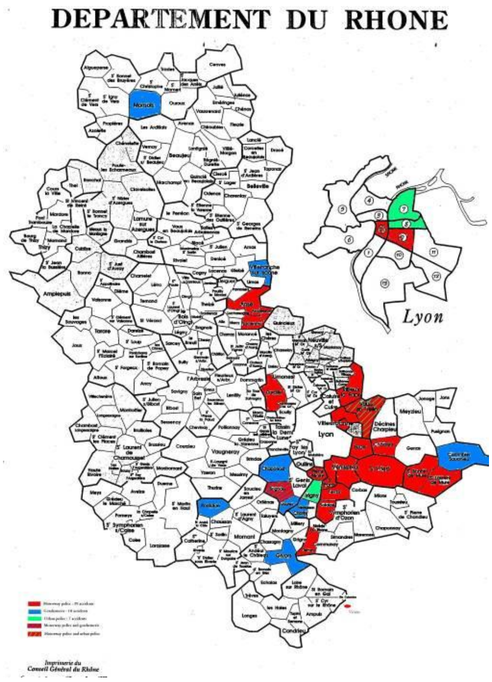
It was also recognised that the division between car occupant and pedestrian crashes would also vary by team but typically it was expected that there would be at least 90% of cases where the prime focus was a car accident and up to 10% where the prime focus was a pedestrian accident.

Data collection was carried out in specific areas in each of the participating Member States as shown in the following section;

Data Collections Areas

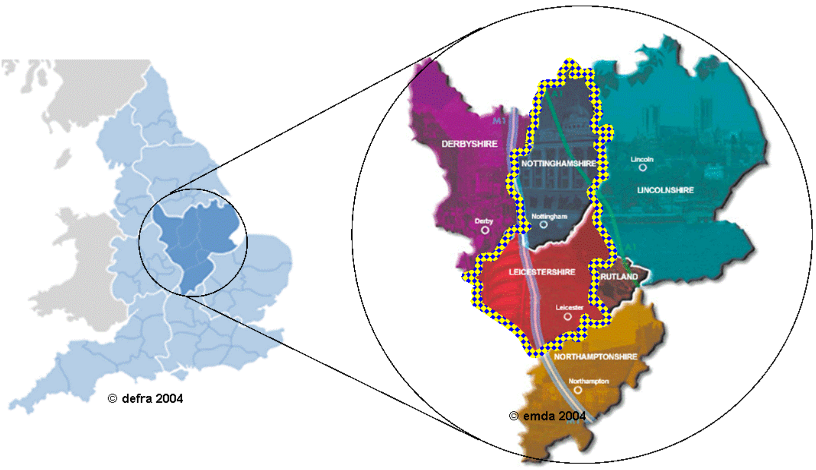
Sampling Regions for PENDANT are as follows:

France (INRETS/ARVAC, Lyon)



The United Kingdom (Vehicle Safety Research Centre, Loughborough University)

VSRC collected data from the East Midlands region of the UK, including the two English counties of Nottinghamshire and Leicestershire,

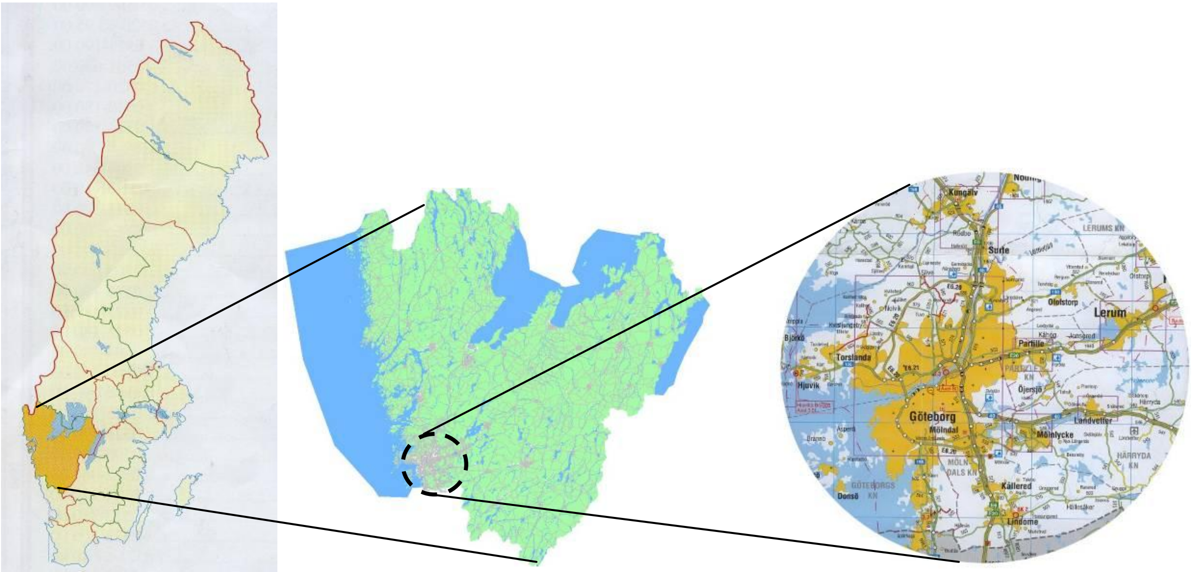


Sweden (Chalmers University, Gothenburg)

CHALMERS

Chalmers University of Technology, Sweden

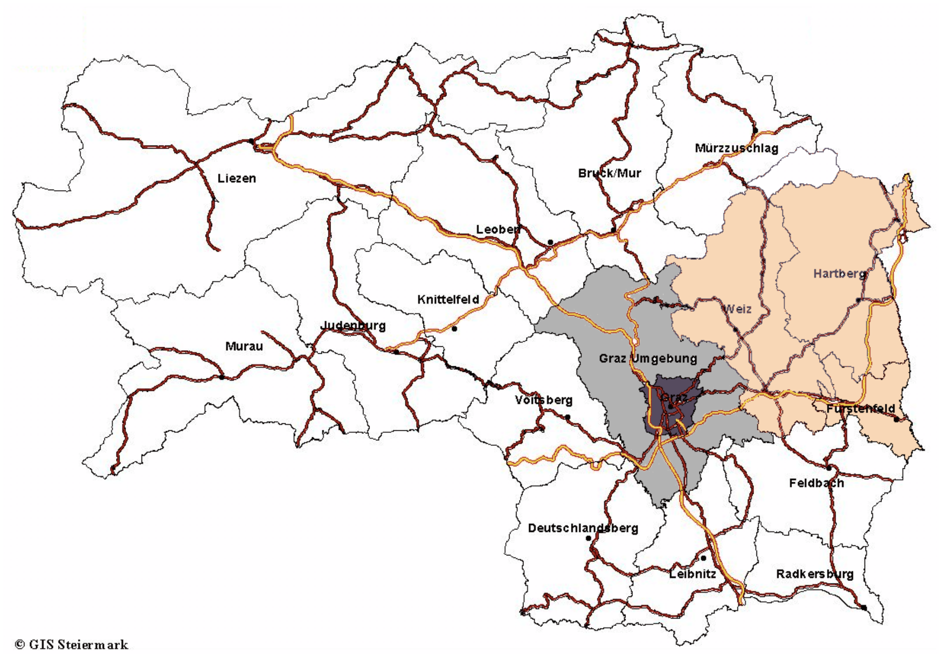
Västra Götaland”, one out of twenty-one counties in Sweden. This county represents approximately 18 % of the population and 6 % of the Swedish area



Sweden ***Västra Götaland*** ***Gothenburg***

Austria (Technical University of Graz, TUG)

The geographical area in which the TUG team operated was the urban and the rural area of Graz which is the grey region in the map. The option to investigate crashes from an additional sampling region (the orange region (Weiz, Hartberg, Fürstenfeld) was added at a later date. The geographical area of Graz urban is approximately 127.570km² and the area of Styria approximately 1.099.400km². Due to the fact Graz University has a stronger relation to the urban police more accidents were collected in the city (dark region in the map). 357,000 people are living within the sampling region.



Spain (UPM – INSIA, University Institute for Automobile Research, Polytechnic University of Madrid)

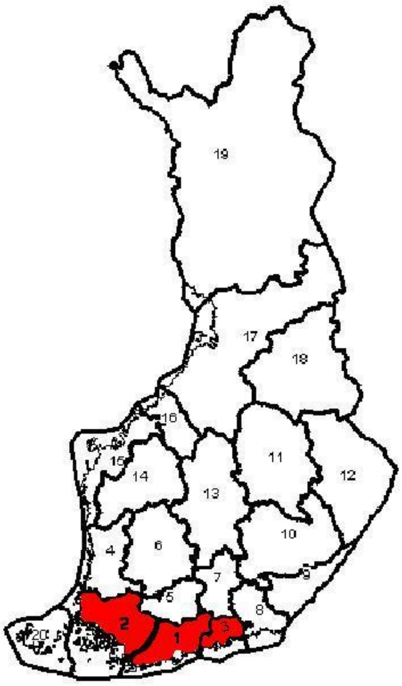
The Spanish area for collecting data by the INSIA team is the Madrid region. This area represents approximately 2% of the Spanish area, but it contains 13% of the Spanish accidents.

Germany (Medical University of Hannover)

The region of data acquisition for the work at PENDANT WP2 at the MUH is the state of Lower Saxony. Lower Saxony is one of 16 governmental states within the country of Germany.

Finland (Turku University, Turku/VALT, Helsinki)

The Finnish team operated within the Provinces of Southwest Finland (number 2 on the map), Uusimaa (number 1) and Itä-Uusimaa (number 3 on the map) excluding the city of Helsinki.



The Netherlands (TNO/SWOV, Delft)

TNO operated in the area Zuid-Holland (or so-called province Zuid-Holland). This province is split up into 4 regions:

- Rotterdam-Rijnmond
- Haaglanden
- Hollands Midden
- Zuid-Holland Zuid

Prototype database and website development

The database was expected to provide the key tool for entering, validating, accessing and analysing the data collected. It was recognised that database development would take place over two phases, phase 1 providing a basic data system permitting each team to enter, modify and store the data. A second phase would be the analysis system to evaluate and check the data and provide a mechanism for analysis. The project website was to act as the communication mode to the world about the project. At the time of the website launch, it contained most if not all of the available reference material for the project including training information. It could then be maintained at a lower level of input to contain up to date information about areas of coding support and other partner material.

Data Analysis and report

It was anticipated that the data analysis task would demonstrate that the conditions for harmonised data collection and exchange had been met. More importantly it would demonstrate the value of such data and its application to policy-making. It was planned that analysis of the collected data would take place at various points in the project. An initial review after the first six months was intended to ensure that crash injury data was being collected satisfactorily by each team. This would also provide an opportunity for a review of procedures. A mid-term analysis was to be conducted after the first year of data collection. The final data analysis, (after the completion of data gathering) would be the main analytic output of the project (and would be a project Deliverable).

Methodology

Data Systems

The basic data collection protocol, including the specification of the core data to be gathered, was developed as part of the FP 4 STAIRS Project that was completed in March 1999.

During the first part of this task, the STAIRS protocol was developed into appropriate data collection forms that were updated to take account of more recent in-vehicle technological developments. The data collection forms underwent extensive field trials at the VSRC and a number of iterations were prepared. The forms included vehicle, occupant and injury data. Additionally the CARE data fields were included in the protocol to facilitate future statistical analysis of the data. Finally some additional fields were included to provide an overview of the accident causation events although not in great detail, as this was not seen to be the main purpose of the PENDANT project. A review of the data collection forms was planned for month 18 at the mid-term review.

The data collection forms and associated documentation including the data collection glossaries (which is largely based on the STAIRS methodology) are as shown in **Deliverable D11, Annex 1**

Sampling Criteria

It was decided that the case selection criteria (for inclusion in the database) would be 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).
- M1 and N1 Passenger vehicles manufactured on or after 1st January 1998 involved in crashes with pedestrians
- 20% of the sample of accidents collected by each data collection Centre to be of MAIS 3+ injury severity.

The remaining accidents would be sampled randomly from the geographical regions in which teams operated.

At the first 6-monthly Steering Group meeting, an agreement was reached to investigate a small number of pedestrian accidents. It was decided that a maximum of 10% of the required case-load for each partner could comprise pedestrian crashes.

Training and Support for Data Collection Teams

The first training course for PENDANT data collection specification was held in Lyon on 23-26 June 2003. The topics covered included:-

- Introduction to crash investigation.
- On-scene crash investigation techniques.
- Retrospective Crash Investigation Procedures and Techniques
- The PENDANT Data collection forms.
- Introduction to the Principle Direction of Force (PDoF) and the Collision Deformation Classification (CDC).
- Forensic evidence in crash investigation – what to look for.
- Damaged-based Crash Severity.
- Scene-based Crash Severity.
- PENDANT Sampling.
- Injury Scaling.
- What is expected of a PENDANT case

- Database developments to date.
- Injury correlations.

Figure 7 - Training at INRETS, France

The course provided the key information for the main crash investigation areas, including infrastructure development for the teams. A follow-up training course, addressing collision severity and injury scaling was held in January 2004.

At the start of the project, each team was known to have its own crash investigation infrastructure, involving police, hospital and other contacts. These local networks were seen as an indispensable part of the crash investigation process but they had been put in place for other projects - it was necessary to ensure that the data collection networks in each partner Member State would provide an appropriate sample of crashes meeting the selection criteria.

Expectations of a Team Collecting PENDANT Data

There were certain expectations of each team that was appointed to collect data for the PENDANT study. These were as follows;

1) Team Members
Ideally, it was expected that the team collecting data would comprise the following members;

- Crash Investigator
- Mechanical Engineer
- Psychologist
- Highway Engineer
- Medical Scientist or Physician

In reality, most teams, whilst able to draw on such expertise from within their organisations, were only able to staff the data collection element with 2 or 3 team members. However, all involved in data collection had expertise in at least one of the required areas of expertise.

2) Investigation Equipment
Data collection for PENDANT was perceived to be a relatively complex activity with many different facets. Teams were recommended to have several different pieces of equipment at their disposal including the following;

- Personal identification
- Tape measures/Laser measuring devices
- ‘Crash’-stands
- Digital camera (plus video recording equipment)
- A variety of tools (sockets, spanners, screwdrivers)
- String, chalk and marker pens
- Good quality torch
- Protective clothing
- Personal health and safety equipment including protective glasses, disposable gloves etc.

In addition, the teams were advised to ensure that all of their members received inoculations against Hepatitis-B, tetanus and other infectious diseases because of the possibility of coming in contact with human body fluids during the vehicle examination process.

3) Contact with Local Infrastructure
Each team was advised to ensure that it initiated and maintained good relations with several organisations within their data collection area. Of particular importance were relations with the following;

- The local Police
- The participating hospitals and in particular, Accident and Emergency Consultants.
- Local vehicle recovery firms and tow-yard operators

4) Data Protection, Ethical Considerations and Team Support
It was expected that each team would need to collect ‘personal’ information on vehicle occupants and pedestrians in the PENDANT study. Therefore each team was expected to ensure that data protection considerations were taken into account. In some cases, the teams were required to seek ethical approval in order to participate.

Additionally each team had its own issues concerning the data gathering process and therefore the WP leader visited each team to review the procedures and to deal with specific local issues. These visits started in June 2003 and were offered as a supporting function throughout the duration of the project.

Data Collection

In general, all teams adopted the same data collection methodologies and procedures although some subtle differences were apparent. The main system of crash notification for all partners was via the Police. However some teams then chose to investigate accidents immediately on receipt of police notifications whilst other teams chose to follow up sampled cases some 2 to 3 days post-crash.

The overall methodology of data collection can be summarised by the following flowchart;

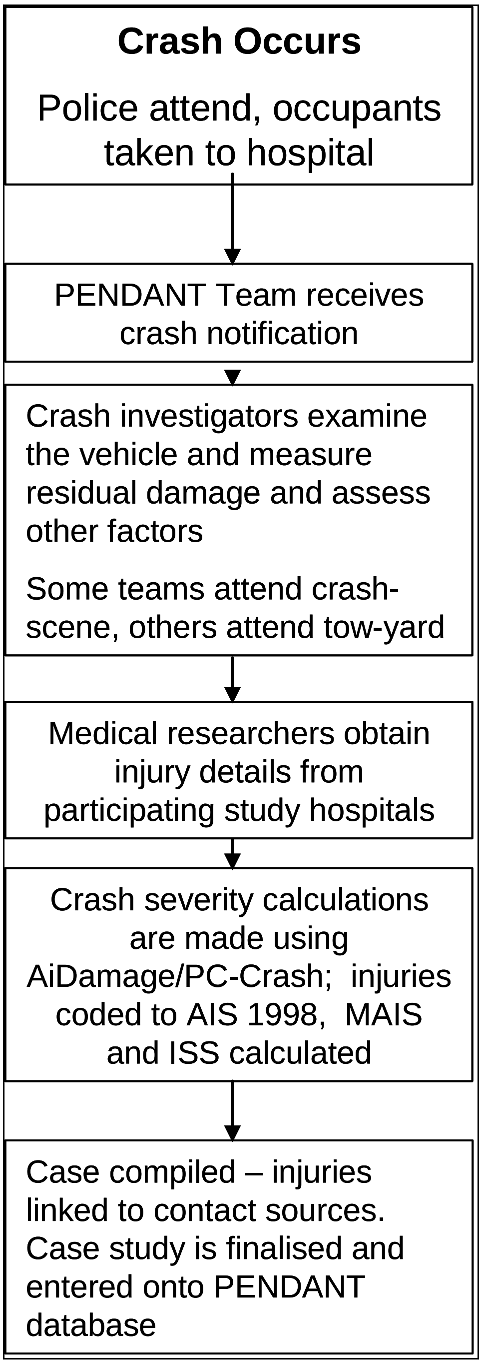


Figure 8 – Flowchart of PENDANT Methodology

For each case sample (see Sampling Criteria), there were a number of data requirements. These related to the accident, vehicle, vehicle occupants and injuries sustained.

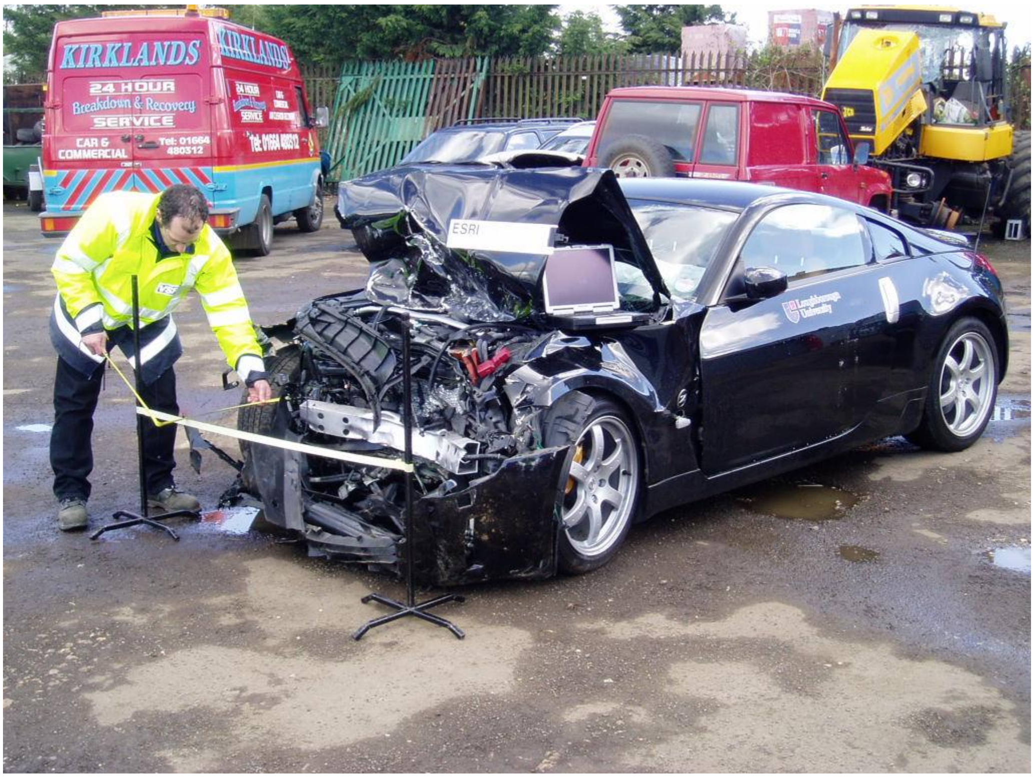


Figure 9 - Vehicle Examination as part of PENDANT Protocol

Accident Level Data

Some factual data was collected for each accident case although the level of data was relatively superficial. The data collection specifications are shown in **Deliverable D11, Annex 1**. Generally, the information collected was in relation to the accident scene including road or junction type, road lay-out and topography and speed limit. Accident causation factors were not seen as a core element of PENDANT and were therefore not collected. The CARE2 variables were seen as suitable for the purposes of data at this level and were therefore used in the PENDANT protocol.

Vehicle Level Data

The vehicles involved in crashes sampled for PENDANT were usually examined either in situ at the accident scene or at recovery garages and scrap yards within a few days of the accident. The procedure for collection of data was the STAIRS protocol. Altogether about 400-500 pieces of information were recorded for each individual passenger car. The vehicles were also photographed extensively both internally and externally. Some key aspects of the data collection included the following;

Vehicle Exterior

The data collected on the vehicle exterior included information on the crash performance of vehicle components such as doors, door latches, pillars, vehicle glazing, bonnet hinges and latches and certain contents of the engine bay. An assessment was made of the structural performance of the vehicle in the crash and therefore the longitudinal members and other energy absorbing structures were examined to assess overall effectiveness.

Where possible, the damage profile of each vehicle was measured so that the crash severity indicators Delta-V, Equivalent Energy Speed (EES) and Equivalent Barrier Speed (EBS) could be attained. Other variables such as vehicle make, model and variant were also recorded.

Vehicle Interior

The data collected on the interior of the vehicle included information on seats and seat performance, steering wheel and steering column, measurement of any intrusion into the passenger survival cell and information on seat belt usage. A key element of the examination of the vehicle interior included an assessment of the effectiveness of the airbags including both frontal and side airbag systems.

An assessment was also made about the likelihood of occupant trapping or ejection within/from the vehicle. It was also necessary to examine each vehicle for the presence of possible occupant contact marks within the vehicle. These were sought in order to identify possible sources of injury from within the vehicle interior and also to establish likely occupant kinematics during the crash.

Impact and Damage Classification and Measurement – Collision Deformation Classification

In order to describe the damage pattern in a manner that is universally agreed upon and readily recognised, the Society of Automotive Engineers (SAE) has devised a descriptive coding method, which conveys the essential features of the collision damage in a seven-digit code. This method of coding is fully described in a booklet entitled 'SAE Recommended Practice J224b'. The code is known as the Collision Deformation Classification or CDC. The code describes the nature and location of direct contact to the vehicle for each collision it sustains. However, in accordance with the protocols of STAIRS, this system has been enhanced to an **8** digit alphanumeric code

Example:

0	1	F	D	0	E	W	3

The first two columns, fifth and last columns are numbers. Columns three, four, six and seven are letters. The first two columns are made up of two digits which describe the direction of force (DoF) of the impact. This is determined by the super-imposition of a clock-face onto the vehicle. The DoF is thus split into twelve 30-degree sectors as on a clock-face, so that a DoF of 12 o’clock implies that the impact was applied longitudinally from the front of the vehicle, as is often the case of a head on collision. Thus a DoF of 06 o’clock implies that the impact was applied longitudinally from the rear of the vehicle. For each side of the vehicle there are potentially 7 directions of force.

If an impact should occur at an angle greater than 15° to the horizontal of the vehicle (at the time of the impact) then the 00 DoF is used.

The third column describes the side of the vehicle most damaged by the direction force of the impact.

Table 6 – Description for side of vehicle most damaged

F = Front

B = Back

L = Left side

R = Right side

T = Top

U = Underside

The fourth and fifth columns describe the horizontal location of the direct contact damage by splitting the vehicle width or length into bands as follows:

Table 7 – Description for horizontal location of damage to vehicle

Front/Rear Impacts	Side Impacts
R0 = ¼ from right side excluding longitudinal	F0 = Front compartment
L0 = ¼ from left side Excluding longitudinal	P0 = All of Passenger compartment
R1 = ⅓ from right side	P1 = Passenger Compartment - Front seat
L1 = ⅓ from left side	P2 = Passenger Compartment - Rear seat
C0 = Centre (engine width)	B0 = Rear compartment
Z1 = ½ from right side	Y0 = Front and passenger compartment
Y1 = ½ from left side	Y1 = Front compartment and front seat
Z0 = ⅔ from right side	Z0 = Rear and passenger compartment
Y0 = ⅔ from left side	Z1 = Rear compartment and rear seat
D0 = Distributed across entire width	D0 = Distributed across entire side

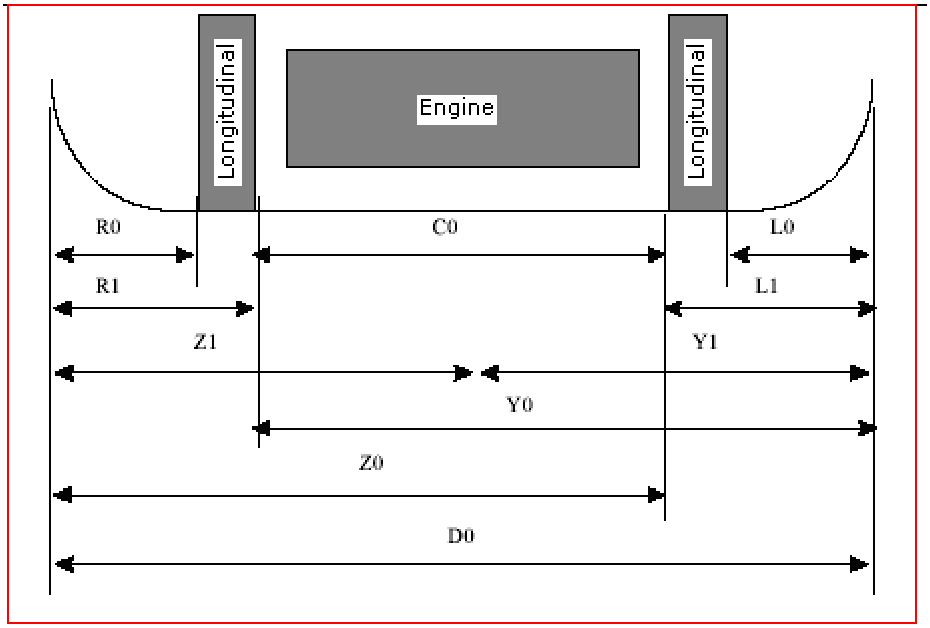


Figure 10 – Frontal impact reference

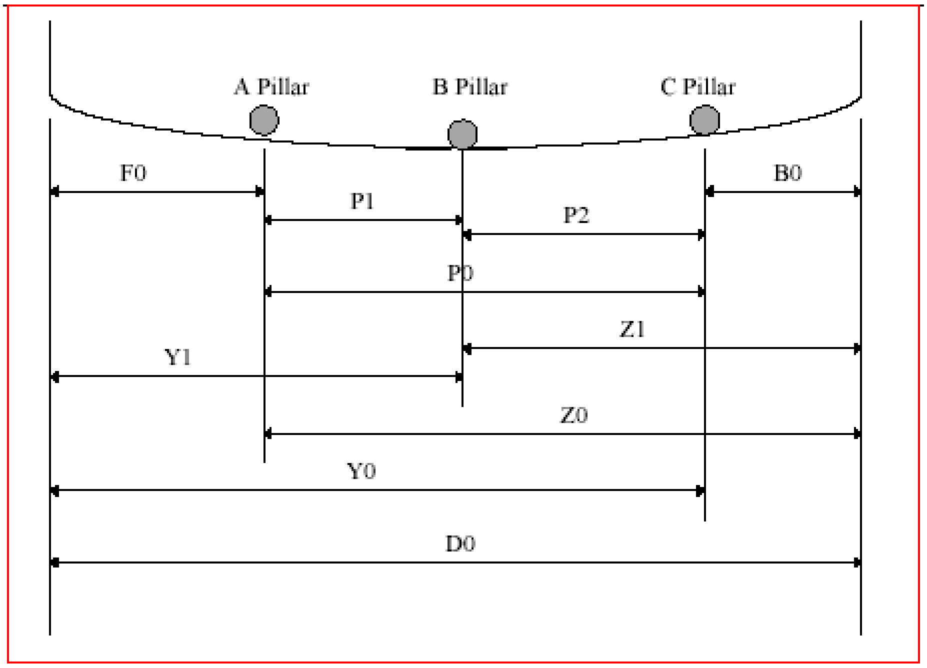


Figure 11 – Side impact reference

The sixth digit describes the vertical location of the direct contact damage. The height of the vehicle is split into bands as follows:

Table 8 – Description of vertical location of damage to vehicle

G = Glass Level & Above	E = Middle & Lower Level
M = Middle Section Only	H = Middle & Glass Level
L = Lower Section Only	A = All Three Levels
W = Wheel/s only	

The seventh digit describes the nature of the impact type once its location has been described. The codes for these are:

Table 9 – Description for nature of impact type

W = Wide Impact (>41cm)	N = Narrow Impact (<41cm)
S = Sideswipe or endswipe (<10cm)	O = Rollover/Overturn
A = Under-run Impact	E = Corner Impact (<41cm)

The eighth digit describes the extent of the crush using a zonal system code of between 1 and 9.

(1) Damage Measurement

Damage measurements are taken to provide a damage profile for the crash reconstruction programmes used in PENDANT. These measurements are taken across a measured width or length to a measured datum line. The minimum number of measures taken is three though it is more usual to take six measures of crush evenly spaced. These measures are referred to as C1, C2, C3, C4, C5 and C6.

C1 is always on the left side for a front or rear impact.

C1 is always at the rear in a side impact.

C6 or the last measure is always on the right side for a front or rear impact

C6 or the last measure is always at the front for a side impact.

(2) Collision Severity - Definitions

(i) Equivalent Energy Speed (EES)

The term Equivalent Energy Speed (EES) has been defined by Burg, Martin and Zeidler in the year 1980 and was suggested for a common use. EES is a speed measure which will be transformed into deformation energy during the collision.

The plastic deformation energy of the damaged car is expressed as a kinetic energy of the car with the virtual velocity value EES. For an authentic EES-estimation various crash-tests with different conditions are necessary, because the energy absorption depends on various parameters.

Two phases can be distinguished during the crash of a vehicle: there is a compression phase and a restitution phase. The compression phase lasts from the contact of the vehicle with an obstacle (another vehicle or anything else) to the point of maximum compression. During this phase, the energy is stocked until the maximum deformation. The restitution phase begins when deformation is at maximum point and ends when the vehicle separates from the obstacle. During this phase, the deformation energy is released.

International Standard definition for EES (ISO/DIS 12353-1:1996(E)): *„The equivalent speed at which a particular vehicle would need to contact any fixed rigid object in order to dissipate the deformation energy corresponding to the observed vehicle residual crush.“*

Unlike delta-V, EES is a scalar quantity, having magnitude (e.g. 50 km/h) but no direction. As the name implies, it is a measure of the energy dissipated by a crashed vehicle and may be thought of as an energy-based measure of impact severity. EES values can be calculated for different types of vehicles using various approximation equations. If one EES is known, it is possible to determine the EES of the second, random vehicle. It is likewise possible to determine the deformation energies in the case of a collision with a stationary deformable obstacle. No direction is assigned to this quantity and it is therefore a scalar. The deformation energy can be written as follows:

$$E_D = \frac{1}{2} \cdot m \cdot EES^2 \qquad [Nm]$$

Where:
E_D: deformation energy
m: mass of the vehicle [kg]
EES: Energy Equivalent Speed [km/h]

EES depends only on the energy dissipated, *ED* and the mass of the vehicle, *m*. These two parameters are not sufficient to determine the change of velocity Delta-V of a crashed vehicle. If the EES of one vehicle that was involved in a vehicle to vehicle collision is known, then it is possible to determine the unknown EES based on the principle of action equals reaction by approximating the other crush.

(ii) Delta-V

Delta-V is the change in the velocity vector at centre of mass of the vehicle. This change in velocity can be as a result of a change in speed, a change in direction, or both. A vehicle travelling at 30 km/h in a northerly direction which after impact, is travelling at 30 km/h in a southerly direction, has experienced a 60 km/h Delta-V due to the change in direction. If a vehicle travelling 30 km/h stops without changing direction, the Delta-V is 30 km/h. If the Delta-V occurs over several seconds and is relatively small, it usually causes little or no injury. If the deceleration is high over in a small time, injury or death is usually the result.

Definition of Delta-V - “change in velocity of a vehicle’s occupant compartment during the collision phase of a motor vehicle crash (i.e. from the moment of initial contact between vehicles until the moment of their separation)”.

Delta-v is a vector, in other words it is a quantity with magnitude and direction. It is the vector difference between an initial velocity and a final velocity.

The International Standards Organisation’s (ISO/DIS 12353-1:1996(E)) definition of *Delta-V is as follows;*

“*The Vector difference between impact velocity and separation velocity*.”

(iii) Equivalent Test/Barrier Speed (ETS/EBS), Barrier Equivalent Velocity (BEV)

The most common method of testing vehicles is by impacting them against or with rigid barriers. Therefore, the reconstruction of vehicle-to-vehicle collisions is benefited by an understanding of the comparability of barrier impact and vehicle-to vehicle collision. In particular, the relationship between Delta-V and barrier equivalent velocity, BEV, is sought in a form most readily useful to accident reconstruction. In general the vehicle Delta-V is not equal to BEV except in instances where the masses and stiffness of the impacting vehicles have a specific relationship. BEV can be used as an energy comparison and is not the speed change felt by an occupant in vehicle. The barrier equivalent velocity can be calculated for each vehicle. This is accomplished by setting the barrier equivalent kinetic energy for each respective vehicle equal to the damage energy on the vehicle. BEV can also be calculated directly from the damage profile. It involves both magnitude and direction and is therefore a vector. BEV does not assume that the vehicle comes to rest and can take into account a final velocity of more than 0 km/h.

Definition of EBS (Equivalent Barrier Speed): EBS/ETS/BEV is defined as the speed in the case vehicle at which equal energy would be absorbed in a frontal energy impact into a test barrier without bouncing back i.e. an estimation of the velocity change at impact that would be required of a crash test if it were to re-create the same amount of crush that occurred in the real crash with a vehicle of equal mass and stiffness.

(3) Method of Calculation

In the PENDANT project, two methods were used to calculate the crash severity measures. The first involved a measurement of the damage profile of the vehicle and the second involved a calculation of ETS/EES/Delta-V based on the resting positions of the vehicles in the crash.

(i) Calculation of Collision Severity from Vehicle Damage

Calculation of severity measures from vehicle damage involved measurement of a crush profile across the vehicle damage in the method described in the Glossary (Deliverable D11, Annex 1). This usually included a measurement of the extent of the deformation at six points of equal intervals across the damage profile. These data together with data about the Collision Deformation Characteristic (CDC) and data concerning the mass of the vehicle and the occupants were used to calculate the relevant measures. In most cases, this was achieved via an algorithm contained in the software package AiDamage. AiDamage is an algorithm which relies heavily on fairly complex physical principles for its operation. AiDamage calculates the change in velocity of a vehicle from the amount of crush sustained in an impact. By taking measurements from the damaged vehicle and comparing them with an equivalent undamaged car, the crush can easily be measured. This algorithm used in AiDamage is essentially a direct application of the principles of linear and angular momentum. Generally the programme produces a better approximation in front impacts than in side impacts as the stiff structures on the side of the car are at the wrong level to resist loading from other vehicles and also the extent of crush is dependent on the impact site. At the front of most vehicles exist collapsible cross members which have been shown to collapse at a uniform rate and the programme takes this into account.

However acceptable estimates of ETS/EES/BEV and Delta-V can be attained in side impacts.

Delta-V makes use of the same damage profile in order to calculate velocity change at the time of the impact.

Delta-V can only be calculated when the vehicle collides with a stationary object such as a tree, pole, lamp-post or it collides with another vehicle whose damage profile can also be measured. In this research, where Delta-V could not be calculated, ETS was used. Both Delta-V and ETS are useful measures of collision severity but neither are exact measures.

(ii) Calculation of Collision Severity from Rest Positions of Vehicles

For those teams using an at-scene approach to accident investigation, it was possible to calculate the collision severity from the rest locations of the vehicles using the PC-Crash Reconstruction Programme. PC-Crash is an accident computer simulation program based on Microsoft Windows. PC-Crash uses a discrete time approach to solve the trajectory of a specified vehicle with user-defined initial conditions. The vehicle dynamics are defined by Newton's Second Law, and the vehicle and tyre kinematics are updated for each time step. The collision model is an impulse-momentum model. Linear momentum and angular momentum are conserved, and energy loss during the collision is estimated with the use of a restitution coefficient. Sliding impacts are handled with an inter-vehicle contact plane and a friction coefficient. Based on the inputs, a crash impulse vector is calculated, which causes a linear and angular velocity change of the vehicles. Multiple impacts can be simulated in PC-Crash. A limitation of the impulse-based collision model is that there is no collision duration and the fact that the collisions are based on the same shape of crash pulse. Nevertheless a force based model is also included, which allows to resolve the contact forces over time. Pre- and post-crash vehicle movements are calculated with a trajectory model, which is based on a time-forward vehicle dynamics kinetic simulation.

In some situations, neither ETS/EES nor Delta-V could be calculated by AiDamage. For example, collision severity is generally invalid in the following situations;

- (i) The damage was due to a rollover;
- (ii) The principal direction of force was non-horizontal (>15 degrees from horizontal);
- (iii) The collision was with an object that broke away early in the collision sequence;
- (iv) The vehicle damage was due to gross under-ride that engaged only the passenger compartment (i.e. missing the 'stiff" region of the vehicle side or front);
- (v) The vehicle was involved in a 'side-swipe' or 'end-swipe' such that there was no common velocity between the two vehicles in the crash and
- (vi) The vehicle sustained gross or catastrophic damage with a loss of basic structural integrity.

Occupant level data

Data were collected regarding each occupant who attended casualty. Generally, this included each occupant's age, sex, date of admission to casualty, date of discharge, date and time of death (where appropriate) and level of consciousness on arrival to casualty (where appropriate). The occupant's seated position in the vehicle was also recorded as was the seat-belt usage which was determined according to the following protocol;

(1) Seat-Belt Usage.

In this study, there were 3 classifications of belt-use these being 'used', 'not used' and 'use claimed'. These classifications are described in turn.

(i) Seat-Belt Used

The 'used' classification implies that there was good evidence that the occupant wore his/her seat-belt in the collision. Evidence of seat-belt usage could be derived from either markings left on the restraint system after the collision or by the pattern of injuries sustained by the vehicle occupant. Normally, when restraining forces act upon the occupant in the collision, then the belt webbing is impressed against the belt swivel and buckle tongue which are usually coated in plastic. In these circumstances, the weave of the belt leaves an imprint on the plastic which is visible to the naked eye. Occasionally, scuffing of the plastic coating occurs such that the plastic is transferred to the webbing itself (figures 12 & 13). Marks are also left on the webbing due to the webbing moving against the occupant's clothing and/or seat. A correctly worn belt may also result in bruising to the occupant. This occurs generally along the strap path so any occupant who received bruising to the chest, abdomen and/or shoulder was usually deemed to have worn his belt. Occasionally, in the absence of belt transfer marks or injury to the wearer, belt usage could be ascertained by other means. For example, the belt mechanism occasionally jammed while the belt was spooled out. Furthermore, the belt itself was occasionally cut by rescue services in order to release the occupant, a clear indicator of usage.

Figure 12 - Marks on belt tongue

Figure 13 - Marks on belt webbing

(ii) Seat belt Not Used

The 'not used' category was applied when there was good evidence that the occupant did not actually wear his/her belt. That is, none of the belt markings as described above were found and the occupant was not injured as would be predicted by belt use. Furthermore, damage within the vehicle interior as a result of occupant interaction with the interior structures was taken as evidence of non-belt use. That is, in these circumstances, it would have been unlikely that the occupant came into contact with such structures if the belt had been worn.

(ii) Use Claimed

The ‘Use Claimed’ category applies when the above definitions are not met, yet the occupant of the vehicle through interview or medical examination states that the seatbelt was worn.

This information may be gathered from medical notes where the occupant states that the seat belt was worn yet, through a vehicle examination, no evidence of this was visible either on the restraint system itself or through contacts expected of belted or unbelted occupants. Additionally the occupant injuries will not be present or reflect the loading of a seat-belt - in this case the ‘Use Claimed’ category is coded.

<u>(2) The Occupant Injuries</u>

Injury Data, Injury Classification and the Abbreviated Injury scale (AIS)

Injury data was gathered on each occupant known to have been injured in the collision. Generally, the casualty notes for the occupant were obtained from the Accident and Emergency department of the relevant hospital. These notes were usually completed by Casualty Officers or Accident and Emergency Consultants. Occasionally in the case of seriously injured occupants who required further surgery or a lengthy stay in hospital, it was necessary to obtain notes from the appropriate ward. When the occupants were fatally injured, Post-mortem reports were obtained.

Numerous scales were considered and evaluated for the purposes of injury scaling and coding for the PENDANT project. An immediate recommendation was that the most appropriate scale for the project involved whole-body injury descriptors because of the diverse nature in the pattern of injuries amongst crash victims. Injury scales that deal with single body regions (such as Glasgow Coma Scale, Organ Injury Scale) have limited applicability and are more suited to more specialised research projects.

When consideration was made of the available 'general' injury scales for the PENDANT project, it was evident that the AIS scale has been used in vehicle safety research since its conception in the 1960's. The scale has the ability to be adapted meaningfully to calculate any benefits from introduction of safety countermeasures such as, for example, seatbelt and airbags in passenger vehicles. The ongoing revisions of the AIS system has ensured that changes in injury severity have been updated as medical procedures and hence survivability has improved over time.

In the absence of an 'ideal injury scale', it was recommended that the PENDANT project utilises the injury scale that is most relevant and can be most easily used by all partners which was deemed to be the **AIS 1998 revision**. Subsequent training was provided for all of the partners in the collection of medical information and coding of injuries (**Deliverable D11, Annex 1**).

The Abbreviated injury scale (AIS) was developed in its most basic form in the late 1960's as a result of aircraft accident investigations at Cornell University (US). The American Medical Association, Society of Automotive Engineers and the Association for Advancement of Automotive Engineers provided sponsorship to organise a meeting where representatives from both engineering and medicine developed a simple set of 75 injury codes to be used in research at government, industry and university levels. These codes were contained in a dictionary that was used as a reference manual to assign the numeric code for an injury such as fractured femur. The code provides a numeric descriptor of the injury and then assigns a numeric severity level to it in terms of the 'threat to life' as shown below.

The AIS code itself is an anatomical descriptor of blunt injuries and does not describe consequences of injury. Therefore the scale cannot be used to assess change in 'threat-to-life' over time due to physiological changes in a person's condition due to initial trauma. For example, an individual who sustains a femur fracture may later die as a consequence of embolism, (which is a complication of the femur fracture), but the injury code allocated would remain the same regardless. However in later editions some consequences of injury have been included to enable more accurate application of codes, for example pneumothorax and loss of consciousness in brain injury.

The severity of an injury based on 'threat to life' on a 6-point scale ranges from minor to untreatable injuries, as follows:

1 = minor
2 = moderate
3 = serious
4 = severe
5 = critical

6 = untreatable (usually non survivable)

Examples of injuries matching severity levels are as follows:

1 = minor (e.g. bruise, abrasion)

2 = moderate (e.g. simple limb fracture)

3 = serious (e.g. base of skull fracture)
4 = severe (e.g. major liver laceration)

5 = critical (e.g. major aortic tear)
6 = maximum (e.g. decapitation)

The full injury code itself comprises an initial six digits with an additional seventh digit indicating severity as described above. It is structured to breakdown into descriptive parts within the AIS98 dictionary:

1st digit = body region (choice of 9)

2nd digit = type of anatomic structure (choice of 6)

3rd & 4th digit = specific anatomic structure or nature (consecutive two digit numbers beginning with 02)

5th / 6th digit = level (consecutive numbers beginning 00)

7th digit = severity (1 to 6 or 9 for unknown severity)

For example, the code for fractured shaft of femur is 851814.3

8 = lower extremity

5 =skeletal

18 = femur
14 = shaft

3 = serious

As with all coding systems there is a reliance on the information contained in the medical notes which if inadequate can lead to under- or over-prediction of the level of severity.

This system was originally designed for use by non-clinicians; however a basic knowledge of anatomy is required to be able to apply the codes. The AIS is also the basis for two further measures of injury severity that have been used widely in studies and within trauma centres. The measures are the Maximum Abbreviated Injury Score (MAIS) and the Injury Severity Score (ISS) and these two measures are discussed below.

The AIS forms the basis of a number of other scores from which data can be presented in a more useable format particularly in vehicle safety research. It also forms the basis of some ‘overall’ severity scores that are used to predict the probability of survival from the injuries sustained and also has the ability to be included within costing calculations of road trauma.

Maximum Abbreviated Injury Score (MAIS)

The MAIS is used predominantly in studies to classify and examine the most severe injuries within body regions to determine changes in injury causation over time. For example, MAIS can be used to compare head injury severity for drivers and front seat passengers pre- and post-seat belt legislation in the UK, providing the same AIS version was used to code all injuries. It is important that the same AIS version is used since over the years some injuries have a reduced severity score attached to them as a result of advances in clinical medicine and hence survivability.

Injury Severity Score (ISS)

The ISS was developed to determine the probability of survival and also provide a numerical descriptor of the overall severity of injury for people with multiple injuries. They found that a non-linear relationship existed between the AIS severity and death. Also crash victims with injuries scoring AIS 4 and AIS 3 did not have the same death rate as someone with injuries scoring AIS 5 and AIS 2, both of which score 7 if summed. Thus they concluded that, by summing the squares of the severity of the 3 most severe injuries in 3 separate body regions, a good correlation was found between total injury severity and mortality. The ISS has a range between 1 and 75, with 75 being the maximum. The maximum score occurs when an individual sustains 3 injuries scoring 5 in 3 different body regions (i.e. 5^2 x 3) or one injury (to any body region) is scored as 6.

The ISS has been widely used to indicate the severity of overall injuries and analysis can be undertaken using this score to examine survival. It has also been widely used within trauma centres to denote ‘major trauma’ if a person scores above a certain level, for example 15.

Pedestrian Data

This section contains information on the process of data collection that leads to a thorough understanding of pedestrian accidents. The methods and procedures for pedestrian accident data collection differ slightly in relation to vehicle only crashes although there is much commonality.

Some of the key data elements are concerned with the general impact pattern on the vehicle, the pedestrian kinematics and both the pedestrian and driver’s behaviour pre-impact.

The data collected is based on the methodology set out in the STAIRS report. This has been modified to enable more in-depth data to be collected in relation to the capabilities and procedures of the accident investigation teams. Further variables have been added on injuries and injury causation; this will enable an understanding to be developed regarding the levels and types of injuries sustained by pedestrians in this type of impact.

The criteria for a pedestrian impact can be defined as any pedestrian injured or killed by a collision with a car or car derivative that is less than eight years old.

Vehicle Data

In order to gain an understanding of the interactions between a pedestrian and a vehicle it is important to accurately measure the vehicle and the damage caused.

Basic vehicle measures involve the heights of three key structures across the front of any vehicle. These measures indicate where the pedestrian first contacted the vehicle and will allow injury coding to be more accurately completed. The three areas are (1) 'Bumper/bull bar height' taken at the uppermost level of such structures, (2) 'Protruding bumper/bull bar height' taken at the height of the maximum protrusion from the ground and (3) 'Bonnet edge height' taken at the level of the bonnet edge to the ground. It is important to remember that these measures are taken at the static height of the vehicle and are therefore subject to dramatic change when in emergency braking situations.

The other vehicle measures involve recording the damage on the vehicle from the pedestrian. These measures provide an indication of the pedestrian's trajectory which is important in impact speed analysis and additional injury coding information.

Essentially the information recorded centres on the impact point from the pedestrian. This damage is normally evident as a head strike to the windscreen or bonnet and will result in a soft dent. This dent will reflect the height of the pedestrian 'hit' and is recorded as measure X (fig 14), the depth of impact dent D is also measured and its orientation from certain datum lines set on the vehicle also recorded.

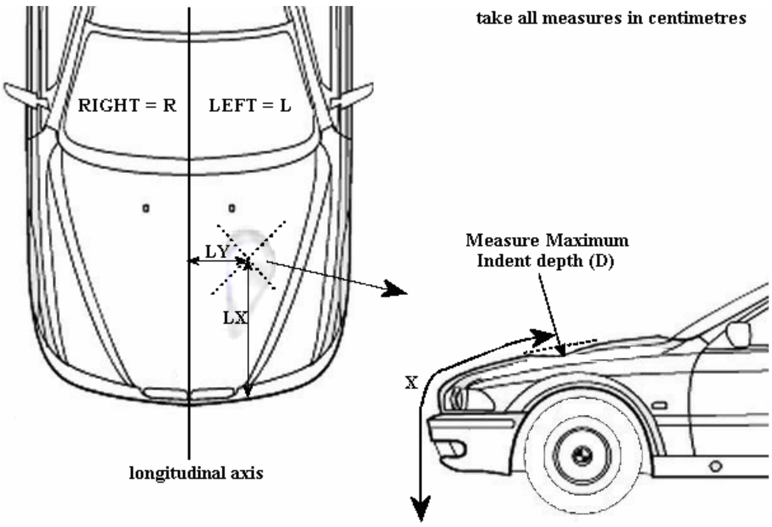


Figure 14 - Measurement of Pedestrian Contact Points on Vehicle Front

The combination of vehicle measures gives an overall impression of the type of impact, direction of impact and severity. It also gives basic biometric information derived from the damage measures.

Behavioural data

In order to understand pedestrian impacts it is not always enough to examine just the vehicle and damage. Other variables including the behaviour and movements of both the pedestrian and driver are also recorded to give an overall picture of the accident scenario.

Pedestrian behaviour covers all the options that could be causal or have an influence in these types of impacts. The variables are all pre-impact and reflect everyday behaviour of pedestrians.

One of the major areas covered in this section is the position and heading of the pedestrian pre-impact. This data contains certain information that can be useful when considering the vehicle damage.

The ‘Movements pre-impact’ and ‘Pedestrian avoiding movement pre-impact’ variables determine the pedestrian’s movement from pavement to impact point. Combining this with the ‘Pedestrian kinematics’ variable is useful as it can determine the trajectory of the pedestrian therefore completing the accident scenario and enabling medical coding to be completed.

The combination of these three variables can be used to describe a situation and help determine causal factors within this. For example it can be coded that the pedestrian hit was talking on a mobile phone pre-impact while also jogging along the pavement. It is clear from this scenario that mobile phones may cause a distraction to pedestrians while crossing the carriageway.

Other information collected relating to the pedestrian includes data on distractions and impairments. This is recorded when a pedestrian is known to have been distracted before the incident or was impaired in any way either physically or through alcohol or drugs.

Pedestrian Medical Coding

For injuries caused in pedestrian impacts it was necessary to utilise a modified accident causation code protocol. This code is the only variation between the methods for coding injuries for car occupants and those caused by pedestrian impacts. The same procedure of recording and assigning injuries is used in exactly the same way in all other non-pedestrian impacts.

The list of causation codes used for pedestrian impacts is modified to reflect the type of hazards that would be presented to a pedestrian struck by a vehicle. These are both vehicle and infrastructure related as a pedestrian is likely to be thrown from the vehicle on almost any path dependent on trajectory, speed, impact type or biometric factors.

Case Compilation

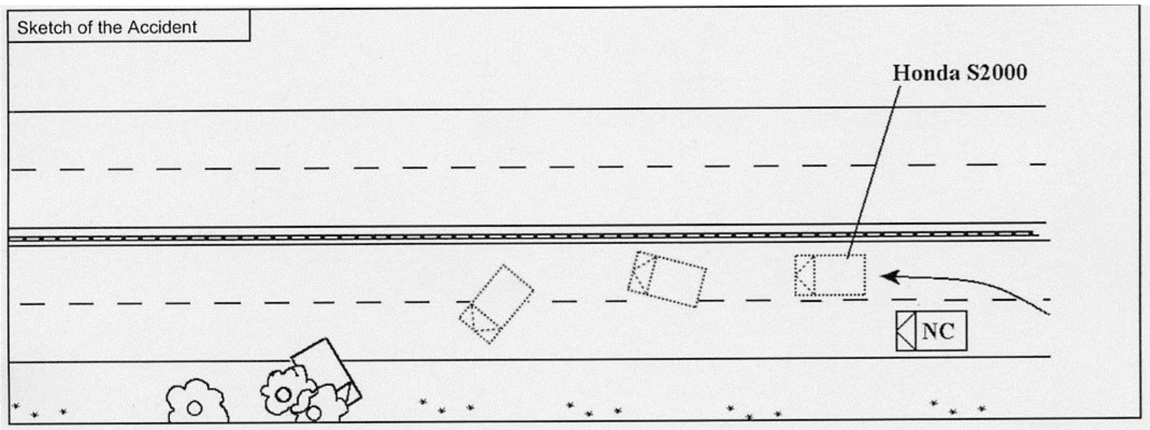
When as much data as possible about the crash had been gathered from the various sources, the data were combined to generate a ‘report’ or case. Each case-file contained information on a number of key elements of the investigation including;

- Accident details including a brief narrative and sketch
- Details of the vehicle damage

- Crash severity details
- Details of the occupants involved
- Details of the injuries sustained by each occupant
- Details of the source of injury

Accident Details

The accident details contained a sketch of the accident event and also a brief narrative of the accident



Account of the Accident

Honda S2000 overtakes slower vehicle on dual carriageway, aquaplanes on wet road, spins off the carriageway and collides with trees

Figure 15 - Accident Sketch and Narrative

Vehicle Damage Details

The vehicle damage details (Figures 16) were recorded on the respective forms. Both internal and external damage details were recorded.

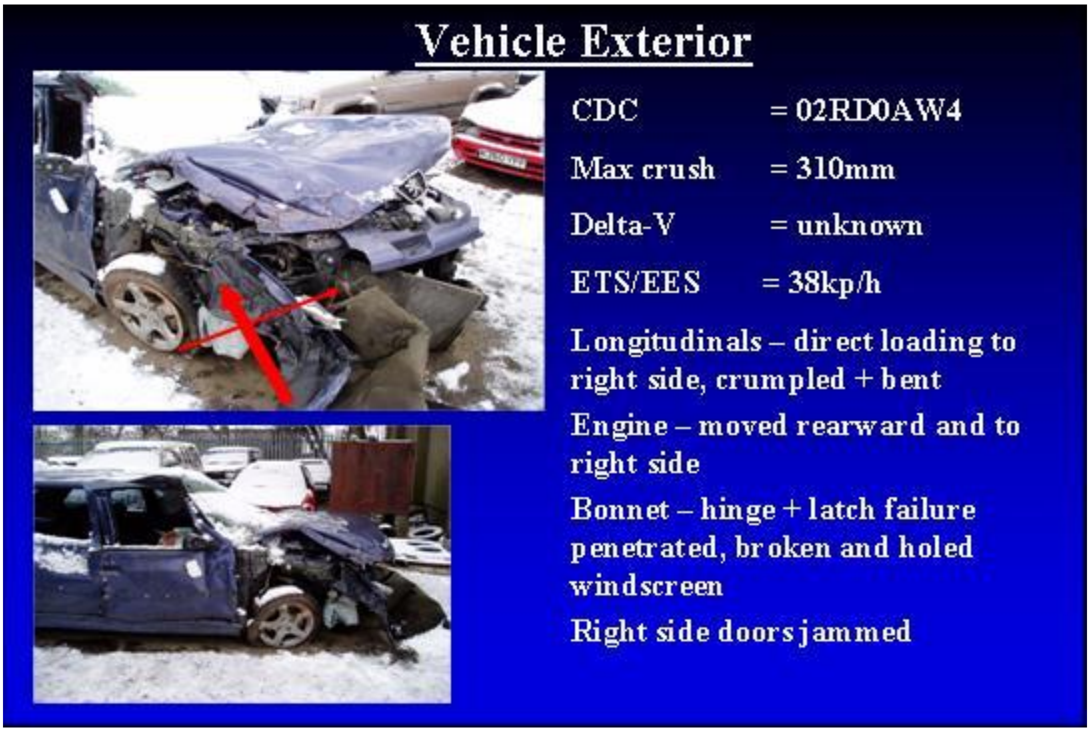


Figure 16 - Vehicle Damage and Crash Severity (Exterior)

<u>Crash Severity Details</u>

The crash severity was calculated (Figure 16) from the vehicle damage or rest-position of the vehicles using either AiDamage or PC-Crash. The outcome severity was measured in km/h. Crash energy, measured in joules was also available.

<u>Occupant Details</u>

Demographic information about the occupant was recorded as was details of seat belt use and airbag deployment.

Injury Descriptions

Injury information including full descriptions of injuries was recorded for each injured occupant. All injuries were coded by medical researchers according to the Abbreviated Injury Scale 1998 Revision. Maximum Abbreviated Injury Severity score (MAIS) and Injury Severity Score were also calculated from the medical detail. An example is shown below;

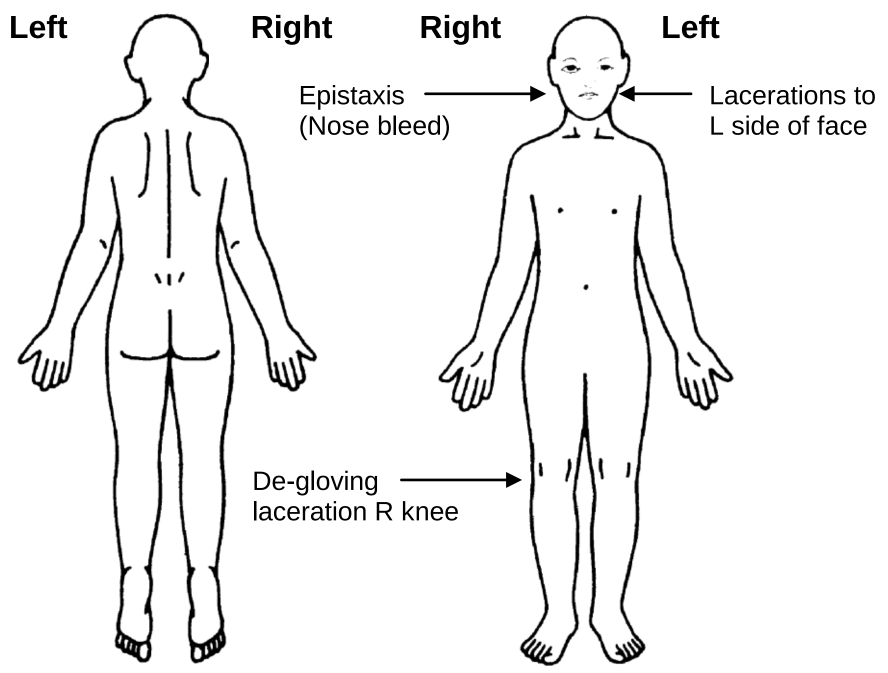


Figure 17 - Example of external injury location

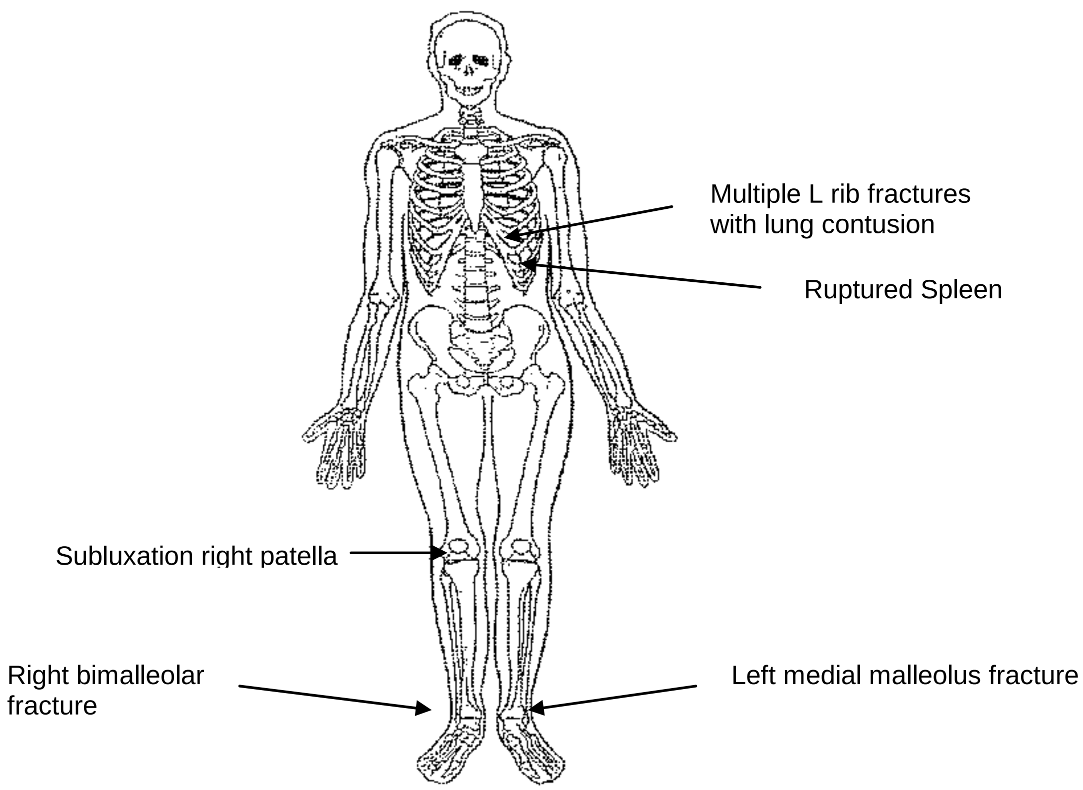


Figure 18 - Example of internal injury locations

Injury Contact and Correlations

The medical information was combined with the vehicle damage details so that an assessment could be made of the origin of the injuries. Generally, occupant motion in the collision was predicted from the pattern of damage on the vehicle. If the motion was indeed apparent, then contacts along the line of motion were also generally conspicuous and injuries could therefore be attributed to interaction of the occupant with these contacts. For each individual injury, a contact source was allocated on the basis of occupant motion (kinematics); evidence of vehicle contact was deduced at the time of the inspection. Individual contact source was also numerically coded in order to facilitate retrieval by computer for analysis purposes.

Table 10 - Injury causation for figures 17 & 18

Injury Description	AIS	Contact source
Ruptured Spleen	5	Seat belt
Multiple #'s left ribs with lung contusion	4	Seat belt
Right bimalleolar #	2	Pedal foot roll-off
Left medial malleolus #	2	Foot-rest roll-off
Laceration to left face	1	Steering wheel
Epistaxis	1	Steering wheel
Subluxation of right patella	2	Lower facia
Laceration to right knee	2	Lower facia

Examples of actual contacts are presented below in figure 19.

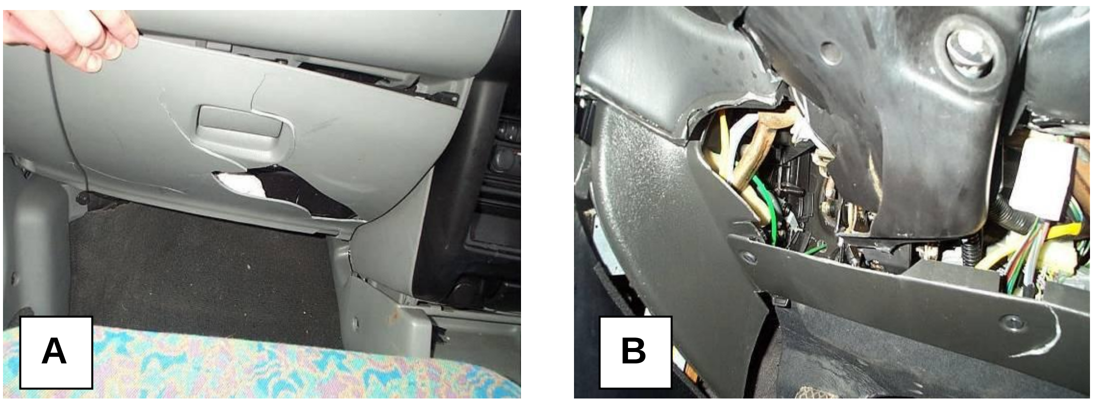


Figure 19 - Occupant contacts

A – Knee contact on glove-box

B – Knee contacts on steering column

C – Head contact on windscreen (unrestrained occupants)

D – Face contact on airbag (lipstick transfer)

The case compilation involved a comprehensive description of the vehicle damage together with details of the calculated collision severity, and a detailed description of the occupant injuries matched to contact sources. In certain circumstances, the injury contact source was unknown as there was no forensic or other evidence to assist in source determination.

In total, the PENDANT Database contains details of 1113 crashes involving 1884 different vehicles of which 1558 were passenger vehicles. The database also contains information on 2370 occupants. The breakdown in terms of partner contributions is as follows;

	Accidents	Vehicles	Occupants
Sweden	150	264	355
France	132	201	296
Germany	171	328	424
Austria	75	152	229
Netherlands	175	326	235
United Kingdom	200	290	445
Finland	80	126	153
Spain	127	197	232
Total	**1110**	**1884**	**2370**

Prototype Database and website Development

A database was developed by TUG and was used throughout by all teams for the purposes of data entry. This database was built using Microsoft Access as a platform.

Database development was conducted in two stages. The first stage prepared a system for data collection and entry while the second added an analysis capability.

Following a number of reiterations, the database was completed as a data entry tool by December 2003.

The Database manual is included in**, Annex 1.** The website was developed ahead of schedule and was made available at http://www.vsi.tugraz.at/pendant/.

The public section is used for general dissemination about the project while the ‘Members Only’ pages are used for document transfer and running information. The site was continuously developed during the course of the project.

Additionally an SFTP server has been installed for combining the collected accidents for analysis issues to get an impression of collection progress before Steering Committee meetings took place.

Data Analysis and Report

Following completion of the data collection in December 2005, there was a significant requirement to undertake substantive quality checks on the data as well as manipulate the database in order to produce a number of data files that could be easily used for data analysis. This proved to be a major undertaking but the resultant data files can now be used as easily analysable data sources that should be used to determine future vehicle passive safety policy and regulation within the European Union.

Data analyses on a number of specific topics and themes were conducted by the partners involved in the data collection activity. However, it is considered that these analyses should not be considered as the definitive end result of PENDANT; the level of detail within the PENDANT data files is so vast that it should be fully exploited and further results produced. The analysis topics that are the subject of Deliverable D11 are those that were judged by the partners to be issues that have current relevance within the European Union. It is expected that other priorities and key topics will emerge during the course of time.

This data analysis itself was also a major undertaking and was a main Deliverable (D11) of PENDANT. The results have been produced as separate Reports which can be found in the Deliverable D11 package as follows;

(1) General Data Analysis
(2) Analysis of Frontal Car-to-Car Collisions - Injury and Compatibility Aspects
(3) Analysis of EuroNCAP Effectiveness
(4) Rear End Collisions
(5) Rollover Crashes
(6) Non-Struck Side Crashes
(7) Pedestrian Impacts
(8) Injury Outcomes in Modern (post 1998) Passenger Cars
(9) Injury Costing Analysis

Hospital based data linked or not to police data

Objectives

The original objectives for this task were:

- to review existing hospital data systems in three countries with regard to comparability of approach, commonalities and strengths of each dataset;
- to specify common data elements and sampling requirements to support interpretation of the co-ordinated datasets involving details of around 50,000 casualties;
- to specify appropriate analytic methods to facilitate co-ordinated analyses without medical data crossing national boundaries;
- to analyse the databases and identify priorities for future European regulatory and other action

Overview of technical progress

The task began with a review of the existing hospital based registrations for the three partners involved in the task (DUHAT from Spain, ARVAC from France, and LMR from the Netherlands). Looking at the different characteristics of the registrations it was soon clear that there are significant differences between the three. These differences made it difficult to adhere to the strict separation of activities described in the contract:

- Task 3.1: Review of existing systems
- Task 3.2: Data Protocol development
- Task 3.3: Analysis Protocols
- Task 3.4: Application/Demonstration

Therefore a more parallel approach was used instead of a sequential one. The overview of the technical progress made in the task starts by summarising the main differences in data selection between the partners. It continues with a brief presentation of the methodology before presenting an overview of the most important results.

Data inclusion

The main differences between the three datasets are the inclusion criteria.

- The Dutch system, LMR, is based on hospital discharge data only, which means that data is only available for hospitalised people (although it is available for the whole country, 16 million inhabitants). LMR records fatalities only if they are hospitalised (i.e. victims that die on the spot are not included). The proportion of these cases among all fatalities is estimated to be very low.
- The Spanish system, DUHAT, is based on people taken care of by the seven emergency departments in the area of Barcelona (1.5 million inhabitants). 86% of these victims are out-patients in the registration. DUHAT records fatalities when they are seen by emergency services. Victims killed on the spot are therefore not always included in the registration.
- The French system, ARVAC, records everyone taken care of by emergency departments, but also medical departments, mobile emergency units as well as forensic departments, inside the geographical area of the "département du

Rhône" (a largely urban administrative area with almost 1,6 million inhabitants). 81% of victims are out-patients in the registration. ARVAC records all fatalities from all possible information sources, including forensic departments. On the spot victims are always included and injury descriptions are available for about 90% of them.

The annual numbers of casualties in the registrations are 16,000 to 18,000 in the Spanish registration; between 10,000 and 11,000 casualties in the French registration; about 18,000 hospitalised in the Dutch registration. As for fatalities it is clear that analysis has to be done separately from those hospitalised for several reasons. It can be supposed that people killed on the spot have different injuries than those who survive long enough to arrive alive at the hospital.

Due to the different data gathering systems outlined above, other differences between the registrations exist:

- For the Netherlands, hospital discharge data means that all information gathered inside the hospital is supposed to be used for defining people's injuries.
- For Spain, information comes only from emergency services. This means that the injury descriptions can be incomplete.
- For France, information comes separately from each emergency or medical unit and is synthesised by ARVAC in a second step. Computerised injury description takes all available information into account.

Differences also exist in how the injuries and their severity are coded for the three registrations. ARVAC uses the Abbreviated Injury Scale (AIS) to code injuries. To each injury code has been assigned a severity level code according to the following code: 1 - minor, 2 - moderate, 3 – serious, 4 – severe, 5 – critical, 6 – maximum. DUHAT and LMR use the International Classification of Diseases Supplementary Classification of Diagnosis (ICD-9-CM) to code injuries. No severity level is associated with ICD-9. In order to be able to compare the data for specific severity levels, a conversion was necessary from ICD-9 to AIS. Translation was possible for a majority of ICD codes, with the associated severity. For more information see D6. In order to summarize multiple injury diagnosis data into patient injury patterns, a second step consisted in converting injury codes into a Barell injury matrix This provides a standard format to describe injuries according to nature and body region. For more detail on Barell matrix see D6.

Another point is how to manage the fact that people can have a variable number of injuries, and that this number varies among the three countries because of the recording systems. LMR records up to 9 ICD-9 codes, there is no maximum number of AIS codes for ARVAC but DUHAT can only record 3 ICD-9 codes. In practice, the great majority of victims have, on average, quite a low number of described injuries (1.8 for LMR, 1.6 for DUHAT and 2.83 for ARVAC). Moreover, the distribution of the number of injuries is very dissymmetric: for ARVAC data, 48% have only one injury described (hospitalised and non-hospitalised patients) and only 3% have 5 injuries or more. As data needs to be as comparable as possible, the MAIS (the highest single AIS code in a patient with multiple injuries) is used to describe overall severity.

2 summarizes the different points, outlined above, which should be considered when comparing the three data sets.

Table 11 - main characteristics of the three data sets

	French data	Dutch data	Spanish data
Source of information	Emergency and medical units, and forensic	Hospital	Hospital emergency
Type of data collection	Active	Passive	Passive
Area covered	Region (urban and rural)	National	City (only urban)
Maximum number of coded injuries	No maximum	9	3
Injury coding	AIS	ICD9-CM	ICD9-CM
Recording of fatalities	All fatalities	Hospitalised fatalities	Emergency fatalities

For the three hospital registrations none of them contain specific accident data like that found in the police data (location, road type, weather, collision type, other parties involved), or in vehicle data sources (make, type, age of vehicles involved). Accident and/or vehicle data have to be linked or matched to the hospital data from other sources such as police registration. Deliverable 7 reviewed the different methods used to link hospital and police data. Below briefly outlines the methodology used.

Data Linkage methodology

The aims of hospital and police record linkage are the same for all three countries.

- to improve the quality of road traffic injury statistics using information from medical records
- to get a better knowledge of injuries according to vehicle characteristics and crash circumstances.

Even if the three linking processes have the same purpose, each country has their own linkage method. As shown above, hospital data sets are quite different. However police datasets seem to be very similar in all three countries. In Spain the Barcelona Police Department (GUB) provides data for crashes with casualties. In France, the Rhone county police data, taken from National police records, are used. In the Netherlands the central registration of traffic accidents from the Ministry of Transport is used, fully based on police information from the entire country.

The key variables used by all countries for the linkage process are date of birth, gender, accident date. Spain and France also used vehicle type of the casualty. Spain and Netherlands used hospital (name). Crash location was also considered important in France, while Spain used position. There are no personal identifiers in any of the linked databases and different methods are used for linkage in each country.

The Spanish process is mainly probabilistic, and partly deterministic; the process is fully computerised. Some final decisions are made by hand to determine whether linked records are indeed for the same casualties. As for the French system it is mainly manual, greatly facilitated by computer software. It allows free unformatted text data as a linking variable. The Dutch system is so-called distance based linking, which more or less follows a probabilistic approach; it is also fully computerised. To be sure linked records are for the same casualties the Dutch decision is built in the linking process using the distance function and an automatically generated quality indicator, leaving 52% of all linked records as properly linked.

In the following Table , the numbers of records used for linking from the two data sources (police and hospital) for each country are shown. The number of linked records is also shown.

Table 12 - Overview of the numbers of records from two data sources (police and hospital), used for linking, and linking results, according to country

Data source		Spain	France	Netherlands
		Years linked		
		(2002-2004)	(1997-2003)	(2001-2003)
Police	killed	123	801	3,008
	seriously injured	1,008	3,784	32,643
	slightly injured	17,455	25,714	83,385
	unknown severity	21,618	-	4.440
	total	40,204	30,299	124,476
Hospital	killed	49	884	1,000*
	in-patients	2,926	11,033	50,420
	out-patients	34,088	56,023	NA
	other/unknown	5,503	1,073	NA
	total	42,566	69,823	51,420
Linked	killed	26	735	635
	in-patients	1,294	5,089	17,257
	out-patients	14,599	13,409	5,613
	other/unknown	1,611	807	667
	total	17,530	20,040	24,172

* estimated

Table shows that the resulting number of linked records are more or less the same (roughly around 20,000), given the different periods used. However, in Spain and France the emphasis is clearly on out-patients. It was decided to use linked data from hospitalised casualties (for all three countries) and linked data from non-hospitalised casualties (Spain and France).

Results Overview

The table below shows the distribution of casualties for the three registrations.

Table 13 - distribution of fatalities and casualties in the three datasets - years 1997-2001

	French data		Dutch data		Spanish data	
killed	665	1.3	1564	1.9	160	0.2
hospitalised	7804	15.3	81668	98.1	9490	10.8
non hospitalised	42368	83.3	0	-	74299	84.5

As there are many differences between the three registrations the following results are based only on those hospitalised as they are the only ones available in all three datasets. Some analysis of the fatalities and the non hospitalised casualties is available in Deliverable 9.

Table 14 - Severity for the hospitalised as estimated by the Maximum Abbreviated Injury Scale (MAIS)

Severity	French	Dutch	Spanish
Number of hospitalised with known MAIS	7773	81668	4812
MAIS1	18.2	14.6	36.3
MAIS2	48.4	55.1	49.8
MAIS3	25.8	26.0	12.8
MAIS4+	7.6	4.3	1.1

The mean severity of injuries is higher for the French hospitalised than for the Dutch ones. The Spanish hospitalised casualties seem to be less severely injured. In spite of the selection of a common group the observed levels of severity are quite different. The differences in mean severity between the datasets can come from the different definitions of hospitalisation and hospitalisation policies that vary from one country to another. It could also come from the different coding systems used by the partners. The method used to translate ICD to AIS could be a partial explanation for the differences.

Among all hospitalised casualties in the datasets, the great majority suffered from injuries with AIS 2 or more in all three countries although to a lesser extent in the Spanish data set. This is in part due to the fact that injury assessment is less complete in the Spanish data, because data only comes from emergency services and in more than 80% of cases only one injury is described. This implies that the number and nature of injuries are under-reported and hence severity. The table below shows the distribution of the road user type for the three datasets.

Table 15 - Distribution of road user type for the hospitalised in the three data sets

Type of road user	French	Dutch	Spanish
Pedestrians	15.7	7.9	38.2
Car users	41.2	26.1	20.1
Motorised 2-wheelers	24.7	18.9	39.4
Cyclists	15.0	40.5	0.4
Others	3.4	6.6	1.9
number with known road user type	7734	81668	4130
number with missing road user type	58	0	5360
Total	7792	81668	9490

- The French hospitalised casualties are mainly car users, followed by motorised 2-wheelers, while the proportions of pedestrians and cyclists are quite close.
- The Dutch hospitalised are mainly cyclists, followed by car users and motorised 2-wheelers. The proportion of pedestrians is quite low.
- The Spanish hospitalised are mainly motorised 2-wheelers and pedestrians, followed by car users. There are nearly no recorded cyclists.

As regards to age and sex distributions, car users are very similar across datasets, as well as pedestrians. Casualties are more often men, and the proportion of males is very high in motorised two-wheelers casualties, especially in French data. This most probably reflects the differences in exposure. As regards to cyclists, French and Dutch casualties probably do not come from the same cycling population at all, as mainly young men are involved in France, whereas males and females are equally involved and at any age in the Netherlands.

These large differences are mainly the consequence of the specific transport mode used in each country (exposure). In view of these differences, the analysis was conducted separately according to road user type: pedestrians, car users, motorised 2 wheelers, and cyclists. See deliverable 9 for full details.

Main findings for injury patterns

Despite all the differences in inclusion criteria and injury coding processes, some common points between the three datasets can be highlighted. These can be considered as the most interesting results of this study, as they provide consistent estimates of injury patterns.

Among all hospitalised road casualties, a great majority suffer from injuries with AIS 2 or more, although slightly lower for the Spanish dataset. For these MAIS 2 + casualties, injury patterns for car occupants are quite different from the other casualties. Their most frequently injured body region is the head, followed by the thorax (except in the Spanish data). Lower and upper extremities follow in very similar proportions. Injuries to the pelvis and the abdomen are also observed, but in lower proportions.

In pedestrians and motorised 2-wheelers, the lower extremity is the most frequently injured body region, followed by the head and the upper extremity, this rank being reversed for motorised 2-wheel users (except in the Netherlands). It was noted that motorised two-wheelers are the road user group that suffer the least from head injuries. This should mean that they most often wear a helmet and that this is effective (even if they are obviously injured elsewhere, as the data only includes those injured). This gives an insight into what improvement could be obtained if cyclists wear a helmet.

Some global results can also be shown when looking at injury patterns by the level of severity. The most severe injuries (AIS 4 +) are head injuries, followed by thorax injuries. This is true for all types of road users, except in car users where thorax comes first. A quite high proportion of severe abdominal injuries are also observed, but only in Dutch casualties. As regards to MAIS 3 casualties, the car user’s category is also different from the others. Thorax injury is the most frequent, followed by lower and upper extremity injuries. For other road user categories, the highest proportion is lower extremity injuries followed by head injuries. For MAIS 2 casualties, pedestrians suffer from lower extremity injuries, followed by head and upper extremity injuries. Car users suffer from head, followed by upper extremity and lower extremity injuries. There was also a higher proportion of spine injuries compared to the other road user categories. Motorised 2-wheelers mainly suffer from lower extremity and secondly from upper extremity injuries. Head injury only comes in the third place. Cyclists most often suffer from head injuries, followed by upper extremity and lower extremity injuries. It should be highlighted that at this severity level a large majority of head injuries are actually loss of consciousness.

The injury patterns for hospitalised road crash causalities do present some similarities in spite of the differences in data selection criteria between the countries. However care must be taken when looking at all the results as differences do exist and it is not always possible to say whether they are real differences or differences that can be explained by different data inclusion methods etc. The main discrepancies are outlined below.

In spite of the selection of a common group, observed severity levels are quite different across the three data sets: for pedestrians, motorised two-wheelers and car users, the MAIS 4+ casualty proportion is about 1% in Spanish data, 5% in Dutch data (2% in cyclists) and 8% in French data (4% in cyclists).

These differences of mean severity in hospitalised casualties can come from the different definitions of who is considered hospitalised. This designation can mean "hospitalised for 24 hours or more", or hospitalised at least one night. If we consider that Dutch casualties are truly hospitalised as data only come for hospitals discharge records, it is possible that the selection criteria for French data were too severe, and that the selection criteria for Spanish data were not severe enough. It can also reveal that hospitalisation policies are very different from one country to another. Given how big these differences are, it is more a question of different "hospitalised" definition than a consequence of the different ways in which road casualties are taken into care.

Discrepancies between the data used can also come from the different coding systems. This can happen because of different mechanisms:

- Levels of details for the description of injuries are sometimes slightly different according to the coding used. For example, AIS 90 code allows a very precise description of head injuries, as well as losses of consciousness. Conversely, ICD 9 code is more detailed for the description of pelvis injuries.
- Because of these differences in precision, the same pattern of injuries can be coded by different numbers of injuries according to the AIS or ICD code. The ICDMAP software use, and the fact that injury description is given by level of severity (for example, only AIS 3 injuries described when considering MAIS 3 casualties) should have minimised these possible differences, but probably not completely.
- For some injury locations and despite the point stated above, descriptions of casualties with MAIS 2+ appear sometimes more coherent than when they are split into the three categories MAIS 2, MAIS 3 and MAIS 4+. A possible reason is a shift in AIS level when translating from ICD to AIS. This can be a partial explanation for the differences, for example, between Dutch and French data for MAIS 3 and MAIS 4+ head injured casualties (higher MAIS 3 and lower MAIS 4 + proportions for Dutch compared to French casualties, for each type of road user). In this way, Dutch and Spanish observations must be coherent and different from French ones. This can only be checked when comparing MAIS 2 and MAIS 3, as the number of MAIS 4+ casualties is too low in Spanish data to be considered.
- Internal organ injuries are not always diagnosed through a clinical exam without medical imaging results. This can explain why the proportion of this type of injury is so low in Spanish data (with only emergency unit information). This can also explain their small number of MAIS 4+ casualties.

At this stage, many differences between the three study samples remained unexplained. The point is then to try to distinguish, on the one hand, true differences due to the different population characteristics (in terms of exposures, risks, etc.) and, on the other hand, differences where we have been unable to identify the origin. Some examples are listed below:

- For MAIS 3 casualties, similar proportions for extremity injuries between French and Dutch data, but mainly upper leg injuries in the Dutch data while balanced between upper and lower leg in the French casualties.
- Very few AIS 3 upper extremity injuries in the Dutch casualties.
- High proportions of AIS3 trauma brain injuries in the Dutch casualties.
- More pelvis injuries in Spanish casualties.

Analyses with hospital-police linked data

The aim of this last part is to take advantage of information coming from the police and hospitals to study possible relationships between crash characteristics and resulting injury patterns and severities.

The choice has been made to focus the following analyses on two crash configurations: car-to-car crashes, with two and only two cars involved (and no pedestrian), and car to pedestrian accidents. More precisely, the specific objectives in this chapter are: (1) to describe the effect of the impacted area on the injury patterns among car drivers involved in car-to-car collisions; (2) to identify the associated factors with injury severity among drivers in car-to-car collisions; (3) to estimate risk factors for a car driver involved in a car-to-car crash to sustain a whiplash; (4) to identify the factors associated with injury severity of pedestrians.

Car-to-car crashes are identified from police data. This assessment could not be made from hospital data, as information on drivers and their vehicles is only gathered when these drivers are injured themselves. The classification of casualties is made according to the following rules: for casualties identified in both data sources, the severity is assessed from hospital data and can be classified into killed, hospitalised, or injured but non hospitalised (MAIS is then available); for casualties only identified by the police, the severity is classified into killed, non injured (if so in the police data) or non hospitalised (if classified slightly or severely injured by the police).

Pattern of injuries and impact area in car-to-car collisions

Because of the differences in definitions of the impact area and the differences in the numbers available according to the datasets, two separate analyses have been carried out, one from French and Dutch observations dealing with hospitalised casualties, the other one from French and Spanish ones dealing with non hospitalised casualties.

Concerning hospitalised people, the most often injured body region is the head, with a very high proportion for right side impact. The proportion is also very high for rear impact, but only for French observations. Most of these injuries are actually losses of consciousness. Chest injuries are the second most often injured region (very close to lower extremities for French data). This high frequency concerns all impact areas, except rear impacts where it is observed half as often. Lower extremities injuries are also quite frequent among hospitalised casualties, mainly for head-on impacts, with a quite equal distribution between upper leg, knee and lower leg injuries. Face and upper extremities injuries come after. Face injuries are more frequent for head-on impacts, and quite rare in case of rear impact for French observations. Upper extremities injuries are mainly the shoulder and the upper arm. Abdomen injuries are more frequent for left side impacts. This trend is even clearer for pelvis / urogenital injuries for this type of impact. Spine injuries, and especially cervical injuries, are mainly observed in case of rear impact.

Concerning non hospitalised people, the most common injury is spine injury, the maximum frequency being observed in the case of rear impact. These injuries are nearly exclusively whiplashes, which are studied in more detail hereinafter. From French observations, it is also shown that neck injuries are quite frequent for rear impacts, while lower extremity and chest injuries are more common for front impact. It can be seen that, even if the number of fractures is lower than for hospitalised, the proportion of people sustaining a fracture and not being hospitalised is not negligible. Otherwise, superficial contusions and sprains and strains are the most common injury types, whatever the impact area.

Coming back to hospitalised data, the French and Dutch observations are quite coherent for hospitalised casualties; the fact that, on average, fewer injuries are described for Dutch data was taken into account. Whatever the impact area, injuries most often observed are head and chest injuries. Spine injuries are more characteristic of rear impacts, and abdominal and pelvis injuries of left side impacts.

These specificities of injury patterns according to the impact area could be of some help to pre-hospital care providers and clinicians who could, for example, have a higher suspicion of internal thorax injury in case of side impact.

Severity risk factors in drivers involved in car-to-car collisions (Dutch and French data)

Three severity criteria have been estimated thanks to the knowledge of injury outcomes for all drivers involved in car-to-car crashes. Risks of being hospitalised when involved in a crash are found to be more often significant than risks of being severely injured (MAIS 3+) when hospitalised. This is not surprising as they have been estimated from higher numbers, but the Relative Risks are also more often higher. This highlights, if needed, that the different risk factors studied have not the same effect according to the level of severity considered.

From the two data sources, compared with rear impact, all other impact areas are associated with higher risk to be hospitalised, and these risks are clearly higher than risks to be severely injured when hospitalised.

Concerning the characteristics of the cars, the protective effect of car mass, as well as the aggressive effect of the opponent car mass, appears more clearly when considering the risk of being hospitalised among those involved than when considering MAIS 3+ casualties among those hospitalised. These results confirm the compatibility issue which is an ongoing research objective.

Drivers with the newest cars are shown less often hospitalised than those driving the oldest ones. This result is quite interesting as it is observed even after taking account of the car mass, which is very important as most recent cars tend to be heavier.

Older drivers also appear more often hospitalised, and this could be the effect of the severity of their injuries as well as the effect of a different taking care policy.

Female drivers appear to be more at risk to be hospitalised when involved in an injury crash, but less at risk to be severely injured when hospitalised (with some caution as corresponding Relative Risk are not always significant according to the data set or the severity criteria). These opposite estimates could be due to the fact that, on the one hand, male drivers are more often involved in more severe crashes, and on the other hand female occupants could be more fragile. Crash characteristics are supposed to be taken account of by the multivariate analysis, but probably not in a sufficient way because of the lack of precise information such as some equivalent energy speed or delta-V estimates.

Factors associated with whiplash in car-to-car collisions (Spanish and French data)

The whiplash injury is the most frequent injury sustained by car occupants involved in a crash. Even if it is most of the time a slight injury, whiplash can have long term consequences and deserves to be carefully studied.

Car to car crashes are identified from police data. Every driver can then be linked with hospital data. When a link is assessed, the corresponding pattern of injuries is known, and in particular the fact that a casualty has sustained whiplash or not. When no link has been established, we have two possibilities: either the corresponding driver is considered non injured by the police, and therefore in the analysis, or he is considered injured, and so excluded from the analysis.

Two important facts are to be noted concerning whiplash: (1) If there is not a more severe injury, most of the time, people suffering from a whiplash are not hospitalised. This means that the recording of those non hospitalised is essential for working on whiplash. That is why we have chosen to work with French and Spanish data only; (2).It is highly suspected that a whiplash is not noted when there is a more severe injury. In this respect, two analyses have been carried out: the first one deals with the comparison of casualties suffering only from a whiplash with non injured drivers; the second one deals with the comparison of casualties sustaining a whiplash and at least another injury to casualties sustaining at least one injury other than a whiplash.

Among drivers sustaining at least one injury other than a whiplash, those who sustain a whiplash have a risk of having a severe injury (AIS 3+) 8 times less often than those who do not sustain a whiplash. Obviously, this observation does not mean that suffering from a severe injury is a protective factor against sustaining a whiplash, but rather confirmation that whiplash injuries are underestimated when there are more severe injuries. Moreover, the proportion of whiplash is about 17.8% among drivers suffering from at least one injury other than a whiplash, while this proportion is 8.6% among drivers sustaining only a whiplash or uninjured. In other words, whiplash is recorded two times more often when casualties suffer from another injury.

Five risk factors can be highlighted:

First, whiplash injuries are most often observed in rear impacts. This was expected; as it corresponds to the main injury mechanism suspected and has been observed in most whiplash studies. However, it is worth noting that even if the risk to sustain a whiplash is higher in the case of rear-end collisions, most whiplash injuries are observed in other accident configurations (as rear impacts represent between 10 and 20% of observed impacts).

Second, female drivers are shown to sustain a whiplash between two to three times more often than male drivers. This is observed even after taking into account some crash circumstances and the car mass (which could have been important as, on average, women drive lighter cars than men, and more often for urban trips). This higher proportion has been observed in most of research papers on the subject. The explanations proposed most of the time is the anthropometric and physiological differences, leading to differences in tolerance to mechanical loading. This could be taken into account in the seat characteristics in terms of shape and stiffness.

Third, car mass seems to be a protective factor, which was expected, but highlights, from a more general point of view, the compatibility issue between vehicles.

Fourth, seat belt wearing appears to be protective when comparing drivers sustaining only a whiplash to uninjured drivers. As there is no problem of underestimation of whiplash due to more severe injuries in this sample, this result seems quite interesting but needs to be confirmed by more in depth investigations, with details on different possible seat belt technologies for example.

Finally, older drivers (65 years or older) seem to suffer less often from whiplash than the others. Again, even if this is not because they are more severely injured, this result needs further work as a physiological explanation is not straightforward, and no such association has been previously shown.

To obtain these results, all medical data was used in order to have a precise injury description, including whiplash, and linked police data to identify car-to-car collisions, to know main characteristics of the crash, but above all to identify drivers involved in the crash but not injured. This last point was essential to take account of the whiplash underestimation in the case of more severe injuries. In spite of the many differences between French and Spanish sampling and injury coding, relative risks are shown quite coherent, and this gives a great support to our estimations.

Car to pedestrian collisions (French and Dutch data)

Over the past years, the EU has made several attempts at introducing legislative measures in order to improve pedestrian safety, and a proposal for a framework directive on pedestrian safety has been presented. It aims to reduce deaths and injuries of pedestrians involved in traffic crashes through changes to the construction of the front of vehicles. In this proposal, four tests developed by the European Enhanced Safety Vehicle Committee will be used. The idea of the following study is to evaluate the possibilities of measuring, from real world accident data, the consequences (and their efficiency) of such future changes.

Car to pedestrian crashes are identified from Police data. Injury patterns are available from hospital data, after linkage with police data. As in the car-to-car collisions study, make and model of the cars are deduced from the Vehicle Identification Number, as are other characteristics of the car such as weight. Two classifications of cars have also been produced: one close to the EuroNCAP one, the second one relative to front of cars, which includes four main categories according to the shape of the bonnet. The analysis focuses on the association between this front of car classification and the injury patterns, as well as the injury severity of pedestrians. The analysis is limited to hospitalised victims from French and Dutch data.

As expected, car to pedestrian accidents mostly occur in urban area. Cars involved are obviously the ones the most frequent on the roads, i.e. the so-called super minis, small and large family cars.

The part of the car which has been noted as impacted is mostly the front, in the centre or not (89% for French data, 79% for Dutch data). More than 32% of pedestrians involved in accidents are less than 16 years old, and 24% more than 64. There are slightly more males (55%).

Considering the proportions of pedestrians sustaining at least one AIS 2+ injury to the specified body region, no difference appears between the different types of car fronts. Lower extremities are the most often injured body region, followed by the head and the upper extremities.

The risks of being seriously injured (MAIS 3+) according to the location of the crash, the type of car, the type of front-end, and the age and sex of the pedestrian are estimated, but the only significant Relative Risk is the one associated with crashes occurring on main roads in French data. In particular no significant association is shown between severity and type of front-end.

The study of Police-Hospital linked data does not make it possible to highlight a clear effect of car characteristics, such as front-end type or market segment, on the localisation and the severity of pedestrian injuries. This does not mean that these characteristics have no effect, but that the available data precision is not sufficient to demonstrate their potential effect. In published papers, the few observational studies showing differences in pedestrian injury severity according to the front-end of cars are more precise than ours, especially on impact areas and equivalent energy speed or delta-V estimations. But only three car categories (sedan, one-box and SUV) are distinguished, while the first category represents more than 90% of cars in Europe. Injuries sustained by a pedestrian hit by a car are in fact the result of complex mechanisms, involving many factors such as the impact speed, the mass, the stiffness and the geometry of the car, the relative positions of the car and the pedestrian at the crash time, the subsequent impact on the ground or with any specific obstacle and the pedestrians own physical ability to take the impact. All this information can not be available from only “standard” police or hospital data, and can only be available from in-depth investigations.

In any case, it can be expected that it will not be an easy task to demonstrate the contribution of new front-end cars on improvement of pedestrian safety in case of accident. To balance the very big variability of impact circumstances, a lot of data with the best possible precise information will be necessary.

With the data used, and going back to the unlinked data, it can be said that the most severe injuries are observed at the head and the chest. Lower extremities are also often severely injured, especially the tibia, the fibula and the knee. Only a few hip injuries are observed. Upper extremities are also often injured.

The European directive project includes tests focused on the head and the lower extremities, but ignores the chest, which nevertheless represents a vital issue.

Methodological aspects of dealing with hospital data

Road accidents cause many fatalities and casualties, with or without after-effects. They are therefore a major public health issue in Europe and elsewhere, it is even more important since they mainly affect the young. For that reason it seems essential to measure the health effects of road accidents by recording as fully as possible injury patterns for all victims. The most direct way of collecting such information is from all the structures likely to provide care for the victims. The three WP3 partners have done just this with different strategies and methods. Linking the hospital data to more detailed information about the accident circumstances from police data seems to be the natural next step. However the linkage came across several problems highlighted earlier in the report.

Evaluation of remaining problems

From the outset of the task it was decided not create a common database for two reasons; firstly for data ownership and secondly because the data available are very different for each partner. Instead of a common database, pertinent data was selected according to what issues we wanted to study and the analysis was coordinated so that the results were as comparable as possible between partners. The work done during the entire project confirmed that this was the right decision.

The main complications essentially came from the differences between the target populations, the selections done by each data source, as well as how precise the medical information gathered was and the way it was coded.

Therefore, with only three partners in this task, there are:

- Three different data gathering strategies: for the entire country, but only hospitalised victims in the Dutch data; for one county, but all road accident victims that are taken into care by all medical structures, including mobile ones, in French data; for the region around a large city and only from emergency services, in the Spanish data.
- Two different levels of precision for injury descriptions; theoretically complete for the French and Dutch data and inevitably incomplete for the Spanish data.
- Two different injury coding methods: ICD9-CM which makes it possible to code all illnesses and AIS90 which is specialised in coding injuries with a severity level associated with each injury.
- Two different linking strategies: one uses a program which makes it possible to link a large amount of data and the other one is “manual” assisted by a computer which means more work but makes it possible to use more information contained in some data.

Recommendations for possible improvements

This report has, where possible, taken into account the differences mentioned above, for example by reducing the populations studied to a common part of each dataset, by converting ICD codes into AIS with the associated severity or by using the Barell matrix. It is however clear that reducing the existing differences would greatly facilitate the common exploitation of the different data. With this in mind some possible improvements can be proposed:

As far as possible, it is necessary to take care with the sampling, the coverage and the various injury coding systems. The way of assessing injury severity also needs to be addressed. The severity index coded manually could vary slightly from those obtained through a software such as ICDMAP. Although it would be better to manually code, it is impossible when using big databases, such as national hospital registries, in this case ICDMAP is a useful tool. Nonetheless it is important when comparing data from different sources or countries to be aware of the possible biases.

A registry approach, such as in France is totally recommendable. It guaranties exhaustive information because it is an intensive and active data collection that covers urban and non urban areas, codes directly to AIS and includes all injury descriptions. Nonetheless it is a quite expensive register as it needs a great number of human resources. On the other hand national hospital records are less expensive because data is systematically gathered for all people hospitalised for whatever reason, the drawback being that there is no information on non hospitalised road crash victims. ICD 9 – CM is less precise than AIS 90 for injury description, but this is less true when considering ICD 10, which is already used in hospitals in some European countries. This could improve the situation, with the condition that a corresponding ICDMAP be available.

Whatever method used to link the medical data to police data, the linked data will inevitably be reduced (and therefore a problem of information loss) and often biased. These biases will need to be identified, estimated and taken into account in the analysis and interpretation

In view of the rather large numbers of unlinked data, regardless of the linking method applied, the use of a unique personal identifier in police and hospital data is strongly advocated. However, because of various privacy aspects of such (national) efforts, this road may still be a long one. In the meantime, linking of data might be facilitated by removing barriers that still exist between those responsible for registration, especially concerning medical data, and those trying to make these data useful for scientific research.

Part of the fact that the (linked) data used in this project did not yield sufficient results (as in case of pedestrian-car accidents) is due to insufficient numbers of these (linked) cases. It is therefore recommended to use bigger samples, either by having more years, larger areas, or more countries.

Conclusions and recommendations regarding future legislation

The health consequences of road accidents are essential knowledge for public health because it defines current issues and makes it possible to monitor eventual changes in public health. It is also important to consider this knowledge in relation to the evolution in road user behaviour, the vehicles and the infrastructure.

Working together with several countries has many advantages; it increases the amount of observations, which may make it possible to better identify some risk factors; but the price to pay for this is the increased dispersion of the measures.

This study made it possible to assess the utility of hospital data on road injuries to complement police data which is usually the most common source of information on road crashes. Some results have been produced, such as the differences in injury patterns between the road user types, or depending on the impact area in car to car collisions, as well as more specific results such as the importance of whiplash injury even in case of slight crashes, or the relatively high frequency of chest injuries when focusing on severe injuries sustained by pedestrians hit by a car.

This study also shows that when high precision is necessary for some data, in-depth investigations, such as those implemented in the WP2, would be more fruitful.

In spite of the limitations, it showed how hospital data, unlinked and linked to police data, can provide information on severity and the nature of injuries according to road user type and crash characteristics. It is especially useful for monitoring and planning international comparisons.

Comparison of planned activities and actual work

There were four objectives for this task at the start of the project which are described at the beginning of this section.

The first aim was to review the existing hospital data systems in the three countries. The approaches used to collect data, commonalities between the three and their respective strengths and weaknesses were all thoroughly investigated and presented in Deliverables 3 and 6.

The three data sets turned out to be quite different as shown above. Common analysis was only possible for hospitalised victims in the three countries. It was possible however to carry out several analyses based on part of the three data sets, i.e. non-hospitalised victims from the French and Spanish registrations.

The analysis done within this task has not really identified priorities for future European actions, apart perhaps from concern about pedestrian chest-injury. It has improved knowledge about different approaches to hospital road crash data and as it is a fairly new area of research it has shown what could be done to improve comparability.

State of the art review

The use of hospital data in road safety research is still fairly recent; the project can be compared to very few other projects. These results improve the body of knowledge and show where future projects should concentrate. It highlights where more detailed data is needed to improve statistical results, for example for detailed pedestrian injury analysis.

List of project deliverables

Deliverable No.	Status and delivery date (M)	Output from WP No.	Nature of deliverable and brief description	Deliverable due date
D1	Delivered month 4	1	Specification of harmonised injury scaling methods for use in WP2 and WP3	Due month 4
D2	Delivered month 6	2	Specification of data to be collected in WP2, Specification of new accident causation data fields	Due month 6
D3	Delivered month 7	3	Report detailing areas of commonality of existing hospital data systems and previous applications;	Due month 7
D4	Delivered month 29	1	a public domain database of sample crashes with accident reconstructions; recommendations and guidelines for harmonised practice to be used in WP2	Due month 29
D5	Delivered month 12	2	A database system to provide data entry, access and analysis functions	Due month 17
D6	Delivered month 19	3	Specification of data coding protocol and transformation procedures for development of comparable datasets;	Due month 19
D7	Delivered month 26	3	Specification of analysis protocols and methodologies;	Due month 25
D8	Delivered month 42	1	Harmonised analytic methods to predict casualty reductions of both accident and injury reduction measures.	Due month 33
D9	Delivered month 46	3	A data analysis, conducted to agreed specifications with the Commission, identifying future priorities in road user injury reduction	Due month 36

D10	Delivered month 42	2	Details of 1100 pedestrian and car occupant injury cases entered onto the database system and available for review and analysis.	Due month 39
D11	Delivered month 45	2	A data analysis, conducted to agreed specifications with the Commission, evaluating the effectiveness of past actions and identifying future priorities in car occupant and pedestrian injury reduction	Due month 42

Collaborations/Associations

The PENDANT project has formed links with other EC funded research projects and other international activities. These are listed below.

1. Safety Rating Advisory Committee (SARAC)
   The project forged good links with the EC funded SARAC project which has the purpose to develop new methods to analyse macroscopic data to assess vehicle safety measures. PENDANT members had observer status in SARAC project activities. One task of SARAC is to combine in-depth passive safety data from several sources in order to identify areas where passive safety could be further improved. Data from PENDANT cases was offered to the SARAC consortium to be used to investigate in detail the relationship between the EuroNCAP test protocols and real-world performance.

- Advanced Protection Systems (APROSYS)
  Links were made with the APROSYS Integrated Project (DG-Research) which has the task of developing a wide range of technologies and test procedures to improve passive safety. Presentations have been made between the two groups so that both have a full understanding of the other projects objectives. It is anticipated the outcomes of the PENDANT analyses will make a strong contribution to the later phases of the APROSYS work.
- Advanced Passive Safety Network (APSN)
  The PENDANT project made enduring and effective links with the APSN, PENDANT project members contributed to several APSN workshops addressing future in-depth passive safety data requirements.
- European Enhanced Vehicles Committee Working Group 21 Accident Studies
  EEVC 21 was formed during the lifetime of the PENDANT project with the objective of providing analyses of real-world accident data to other EEVC Working Groups. The PENDANT data is now regularly used in providing a European dimension to detailed analyses on specific subjects.

Dissemination activities

Various dissemination activities were undertaken during the life of the project, these are described below;

2003
PENDANT - Pan-European Co-ordinated Accident and Injury Databases, Andrew Morris, Pete Thomas. Vehicle Safety Research Centre, Loughborough University, UK. Paper Number 361, Enhanced Safety Vehicles Conference 2003

Overview of PENDANT Project, Andrew Morris, Vehicle Safety Research Centre, Loughborough University, UK. APSN workshop on accident data, Nice

The Fifth Framework Project PENDANT. Andrew Morris, Vehicle Safety Research Centre, Loughborough University, UK.APSN Conference, Paris

2004
PENDANT workshop, Hannover 2004
This was a key event during 2004. The PENDANT workshop was held in Hanover in September 2004. The purpose of the workshop was to disseminate the work of the project and to forge further links with other safety activities. The workshop attracted

over 40 delegates from 14 different countries including the US, Australia and India and 33 different organisations. Presentations of note helped develop links with EU projects RISER (road infrastructure), SARAC, APROSYS, CHILD (child protection in crashes), APSN and SafetyNet.

“Das Project PENDANT – neue Ansätze zur Analyse von Inssassenverletzungen nach PKW-Unfällen”; 83. Jahrestagung der Deutschen Gesellschaft für Rechtsmedizin; Göttingen, Germany; presented by Mario Darok, September 2004

2005

The Progress of the PENDANT Project, Andrew Morris, Vehicle Safety Research Centre, Loughborough University, UK APSN workshop on European Accident Data, Warsaw

Current status of the PENDANT Project, Andrew Morris, Vehicle Safety Research Centre, Loughborough University, UK EuroRAP seminar, Brussels

PENDANT Project Update, Andrew Morris, Vehicle Safety Research Centre, Loughborough University, UK presentation to SARAC 2 project meeting, Prato

Improvement of vehicle and road safety at national and international level; Ernst Tomasch, TU Graz APSN workshop on European Accident Data, Warsaw –

PENDANT - Pan-European Co-ordinated Accident and Injury Databases: Inaugural lecture Prof. Steffan, Graz - Ernst Tomasch

Improvement of vehicle and road safety at national and international level; APSN workshop: Accidentology - what does a larger Europe mean in terms of road casualties and the casualty reduction target?; Warsaw University of Technology, Warsaw, Poland; presented by Ernst Tomasch, May 2005

2006

Final project workshop, Brussels, September 2006

Comparison of single vehicle accidents with cars not equipped with ESP (Electronic Stability Programme) and the assumption cars are equipped with ESP; ESAR Conference; Hannover, Germany; presented by Ernst Tomasch. September 2006

PENDANT: A European Crash Injury Database, J. Lenard, A. Morris, E. Tomasch, J. Nehmzow, D. Otte, L. Cant, M. Haddak, G. Vallet, H. Ebbinger, J. Barnes, Y. de Vries, B. van Kampen, J. Paez, E. Keskinen. *Loughborough University, University of Graz, MUH, INRETS, Chalmers University, TNO, SWOV, INSIA, University of Turku, United Kingdom, Austria, Germany, France, Sweden, Netherlands, Spain, Finland*

Website

The website (www.vsi.tugraz.at/pendant/) continued to be used to disseminate basic information about the project and its results. Following a request from international groups the full in-depth data collection forms were made public to enhance harmonisation of in-depth crash investigations between countries. The crash test website (www.crashtestdb.com), achieved as a result of the task “Methods to assess collision severity” is now public with links from the PENDANT and DG-TREN websites. Upon completion of the project the full set of public deliverables will be placed on the website once approved.

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