Analysis of the In-depth database of real-world pedestrian and cyclist accident cases

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APROSYS SP3

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Executive Summary

An in-depth database of pedestrian and cyclist accident cases across Europe was developed with the express purpose of gathering cases suitable for computer aided model and simulation reconstruction. In total 70 cases were collected including 7 cyclist cases. Once populated, the database was analysed - partly to describe the population and assess how much the in-depth sample were representative of the European epidemiology (Deliverable D3.1.1) and partly to obtain more information on the characteristics of pedestrian and cyclist accidents not available in the epidemiology. The results of the analysis confirmed that the database was representative in most areas and outlined the areas in which it wasn't representative together with plausible explanations as to the reasons. The make, model and year of manufacture of the vehicles in the sample are presented, making reference to the preference for newer cars to be used in the accident reconstructions due to their greater relevance to future designs. Some interesting additional information was obtained, particularly the locations of head impacts, types of head injuries, the relationship between impact speed and injury severity and a comparison between MAIS and ISS.

This report is an additional deliverable not planned at the start of APROSYS. However, in view of the level of detail that was available for analysis and the fact that the in-depth data was shown to be representative of the European epidemiology (despite the small sample size), it was considered that the analysis provided valuable additional information for further understanding pedestrian and cyclist accidents.

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1. Introduction

In order to compile a number of detailed Vulnerable Road User (pedestrian and cyclist) accident cases from around Europe containing sufficient detail for computer–aided crash scenario reconstruction work, an in-depth database was developed in MS Access. As well as designing a relational database with tables containing all the necessary data fields so that the relevant data could be easily transferred from the existing databases of the various institutions, the design of the database forms, queries and reports needed to take into account database navigation, data input and data retrieval for future users. The cases were compiled from five different sources from four different countries (the UK, Spain, Germany and Sweden). Additional data for cyclists was sought, specifically from The Netherlands but unfortunately there was no accident database of car (and car derivative) to cyclist accidents.

2. Contributors

BASC[1] has contributed 24 fatal cases including 1 cyclist on accidents taking place in the West Midlands, UK between August 1997 and December 2003. The BASC cases were selected from the West Midlands coroners office and the data gathered by the author and a colleague. For all fatal pedestrian and cyclist accidents in the UK, a thorough investigation is carried out by police accident investigators. These reports are stored together with hospital records and/or autopsy reports in the regional coroner's office and these were accessed with permission for inclusion in the in-depth accident reconstruction database. Most cases involved a post mortem and therefore include the height and weight of the pedestrian as well as very detailed injury data.

OTS[2] data - collected by TRL[3] and VSRC[4] - has contributed 22 serious cases including 4 cyclists and 3 fatal pedestrian cases from the UK between October 2000 and July 2003.

INSIA[5] has contributed 11 serious and 4 fatal pedestrian cases from Spain between February 2003 and October 2004.

Chalmers University, using STRADA[6] data has contributed 2 serious child pedestrian accidents from Sweden between August and December 1998. These cases contain very detailed information about injuries and contact points but do not include information on the height and weight of the children involved.

GIDAS[7] has contributed 4 non-fatal cases - 2 pedestrians and 2 cyclists from Germany between July 2000 and August 2003.

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[1] Birmingham Automotive Safety Centre (University of Birmingham)

[2] On The Spot

[3] Previously the Transport Research Laboratory

[4] Vehicle Safety Research Centre (Loughborough University)

[5] Instituto Universitario de Investigación del Automóvil (Polytechnic University of Madrid)

[6] Swedish TRaffic Accident DAtabase

[7] German In-Depth Accident Study

3. In-depth database analysis

In the following pages, the database contents are summarised and some of the variables are compared with the UK pedestrian accident epidemiology (1997 – 2001) to gauge how well the reconstruction cases represented the population (since 90% of in-depth cases were pedestrian and 70% of the cases came from the UK). Some GIDAS data is also used for comparison for some variables not available in the UK epidemiology. Also, despite the relatively small sample size, the database yielded some interesting observations on variables not available from the epidemiological studies – particularly concerning injury body region and severity and head impact location on the vehicle. Statistical tests were carried out where applicable to determine significance using formulae from statistical text books [1].

Table 1 – Road user type

Vulnerable Road User type	No. of in-depth cases	% of in-depth cases	% of total UK VRU accidents
Pedestrians	63	90%	66.5%
Cyclists	7	10%	33.5%

Table 2 - Gender

Gender	No. of in-depth cases	% of in-depth cases	% of total UK pedestrian accidents
Male	39	56%	58%
Female	28	40%	42%
Unknown	3	4%	0%

Table 3 – Road condition

Road condition	No. of in-depth cases	% of in-depth cases	% of total UK pedestrian accidents
Dry	59	84.3%	72.2%
Wet or damp	10	14.3%	26.8%
Other (flood, ice, oil, mud)	0	0	0.8%
Unknown	1	1.4%	0.1%

3.1 Pedestrian orientation

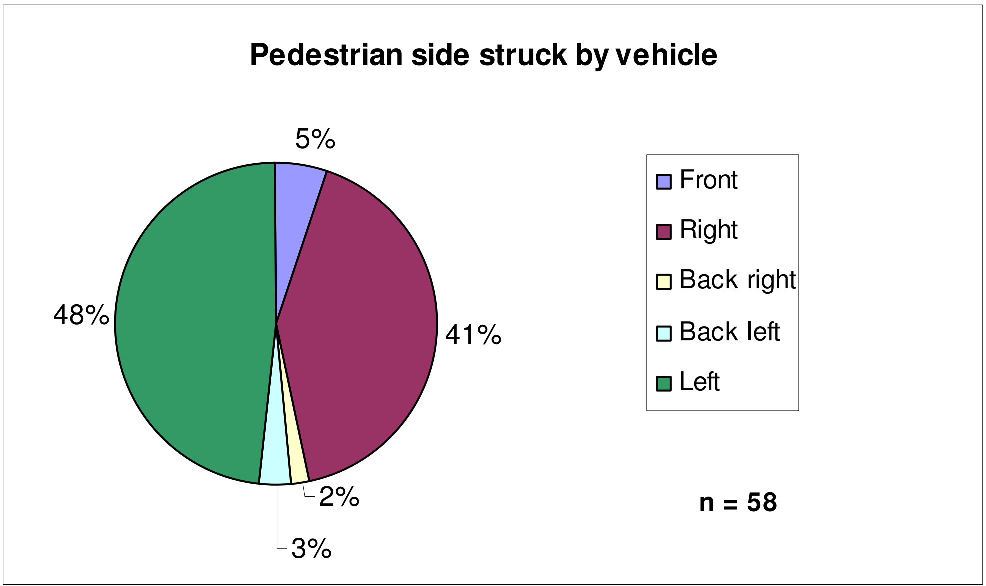

Chart 1 – In-depth sample: pedestrian side struck

In the in-depth sample, 89% of the pedestrians were hit on either the right or left side. From this sample it can be estimated that for a 95% confidence interval (p<0.05), the approximate proportion of all pedestrians hit side-on would be 0.89 ± 0.08 (81% – 97%). The observation that most of the pedestrians in the sample were struck side-on is in agreement with the literature – for example one paper reported that 90% of pedestrians were hit from the side [2] Although the GIDAS epidemiological data that found 65% of pedestrians to have been struck side-on, the difference could be explained by the slightly subjective definition of being struck 'side-on'. Also, the European epidemiology found that between 71% and 78% of pedestrian were struck whilst crossing over the road – a scenario naturally but not always leading to the pedestrian being struck side-on.

3.2 Time of accident

The in-depth cases had an afternoon peak at 5-6pm compared with the UK pedestrian accidents which showed a peak at 3-4pm. The in-depth pedestrian cases didn't have a morning peak but almost half of the cycling accidents occurred between 7 and 8am.

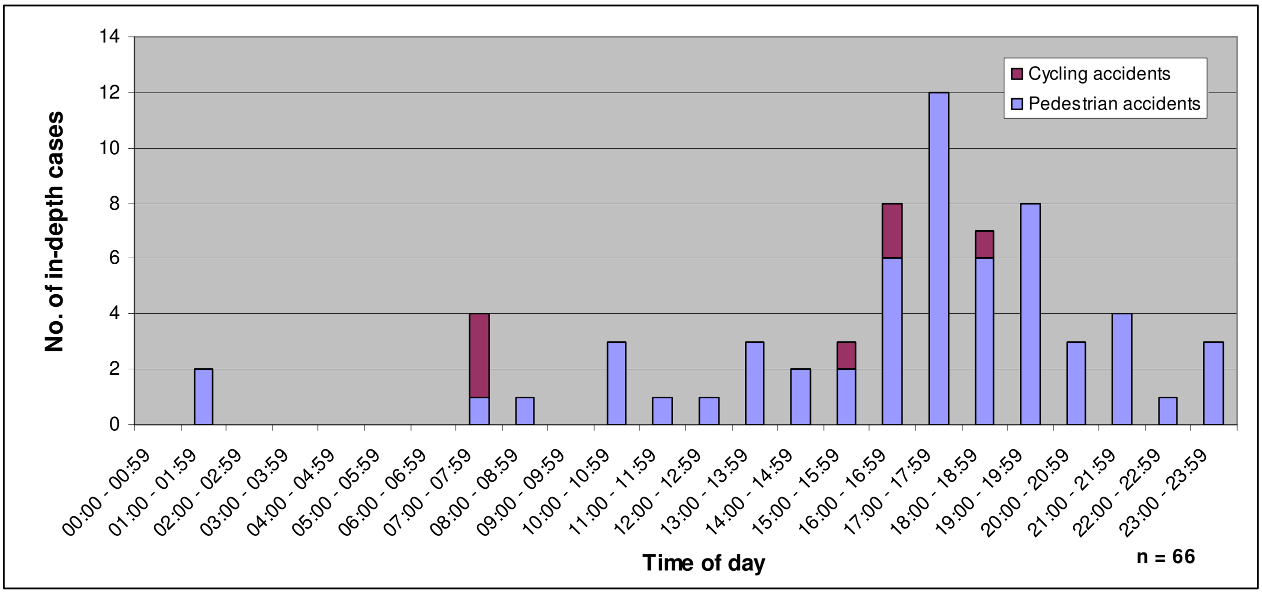

Chart 2- In-depth sample: Time of accident

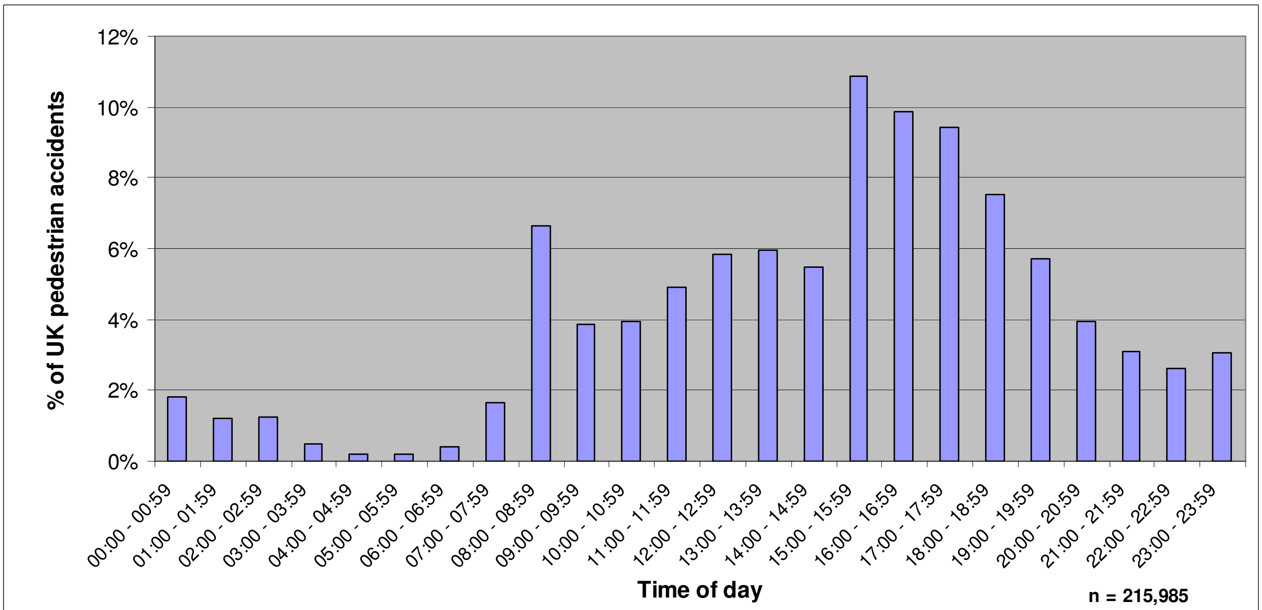

Chart 3- UK pedestrian accidents 1997-2001: Time of accident

3.3 Age

The age of the victim was known for 64 out of the 70 cases. Since the BASC cases were all fatal, they had a higher proportion of older pedestrians than the population (which includes all severity pedestrian accidents) but this was balanced slightly by the other data sources which mostly provided serious but non-fatal cases. The frequency analysis of the whole in-depth sample resulted in the same mode as the UK pedestrian accident statistics (age 11-15) but found that it was over-represented in the older age categories (mainly due to the UK fatal contribution).

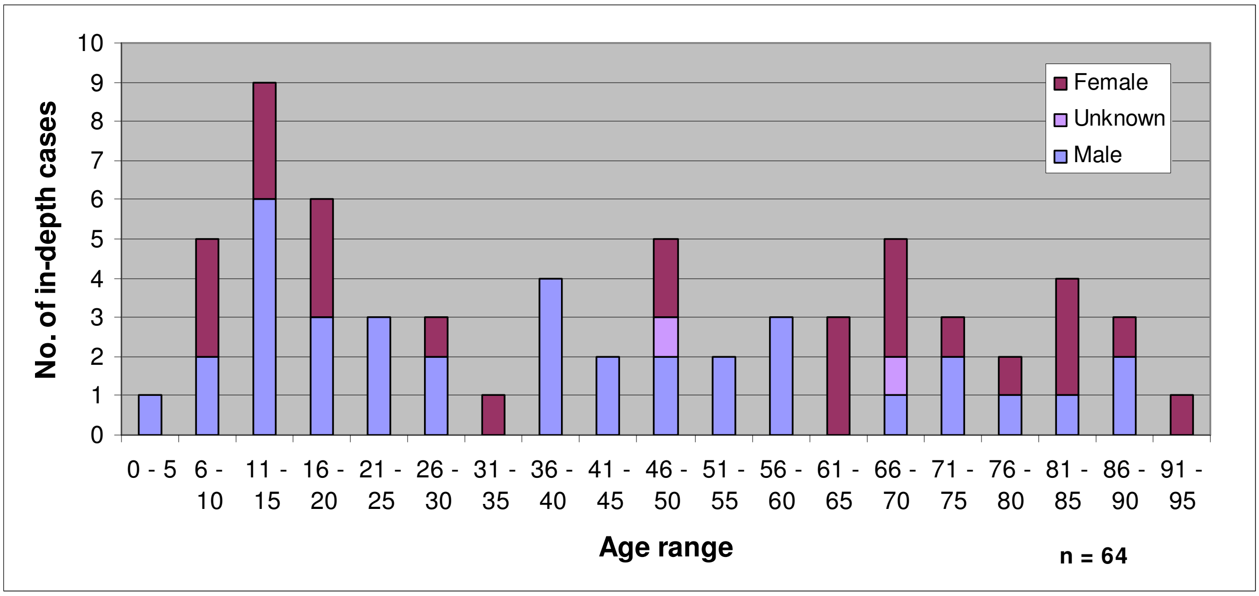

Chart 4- In-depth sample: Age of vulnerable road user

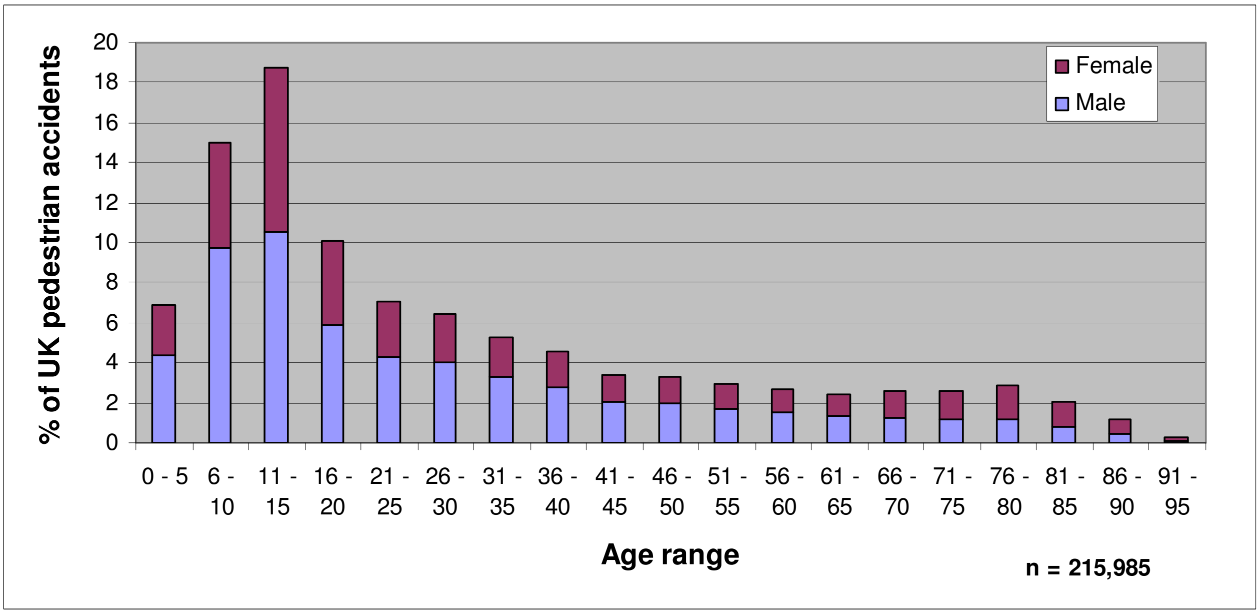

Chart 5- UK pedestrian accidents 1997-2001 : Age of vulnerable road user

3.4 Age vs. Severity

According to several studies and the UK pedestrian epidemiology, the chances that a pedestrian will receive fatal injuries from an accident increases with age. This pattern is less obvious but still apparent in the in-depth sample for which fatal accidents were over-represented as explained previously.

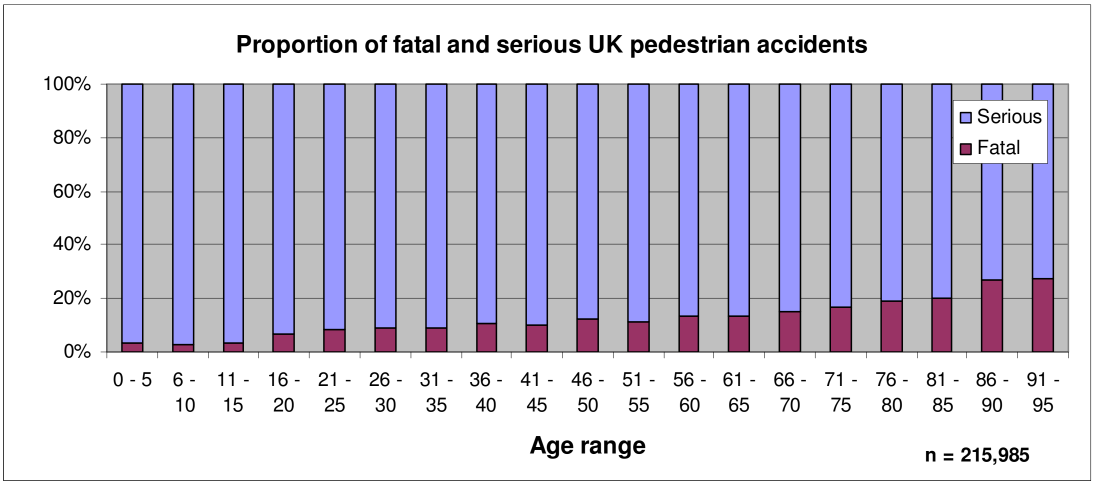

Chart 6- UK pedestrian accidents 1997-2001: Age vs. severity (proportion)

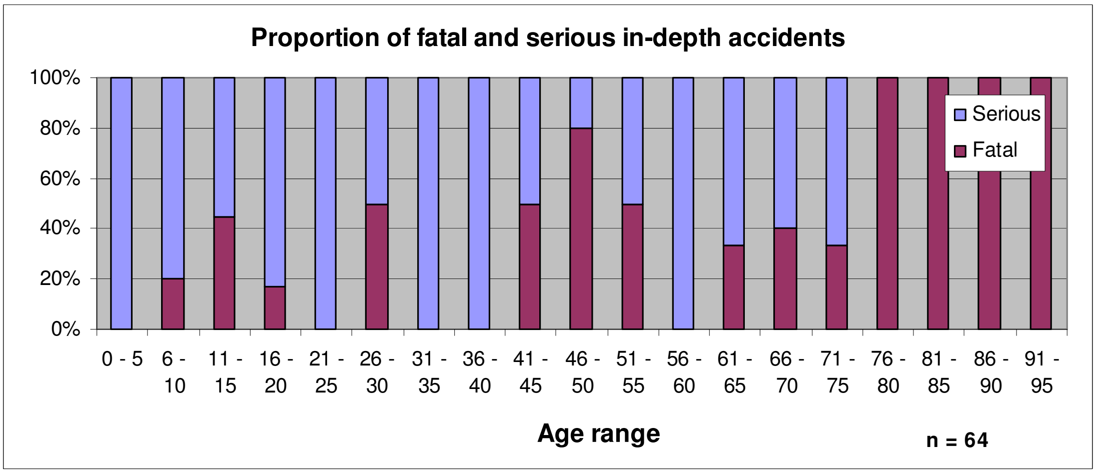

Chart 7- In-depth sample: Age vs. severity (proportion)

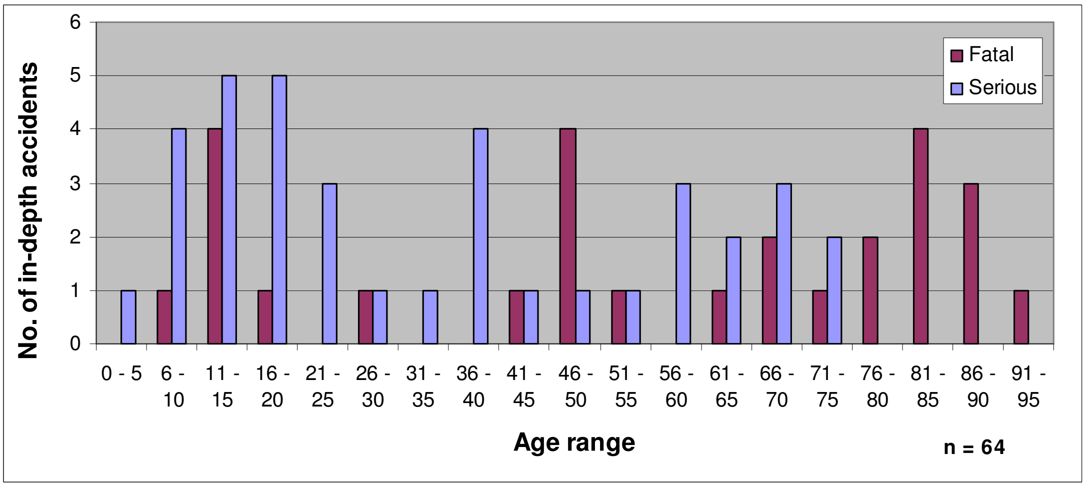

Chart 8- In-depth sample: Age vs. severity (number)

Table 4 – Age vs. severity (comparison with epidemiology)

	Mode (all severities)	Mode (fatal)	Mode (serious)
In-depth sample	11 – 15	81 - 90	11 – 20
UK ped. accidents	11 – 15	71 - 80	11 - 20

This comparison (Table 4) shows the in-depth database to be a reasonably good representation of the epidemiology with respect to age vs. severity.

Table 5 – Age vs. severity (in-depth cases)

	Age (years)				
	Mean	**Median**	**Min**	**Max**	**SD**[8]
Fatal (n=27)	56.2	61.0	10	94	27.6
Serious (n=37)	34.5	28.0	5	75	22.1

Looking just at the in-depth database, Table 5 compares typical ages for serious and fatal accidents. The difference in mean age between serious and fatal accidents is 21.7 years. This difference is highly significant ($p<0.01$).

[8] Standard Deviation

3.5 Vehicle details

The ranges of vehicle makes presented in the in-depth database are shown below. This is probably more a reflection of the European car market than a higher probability for a particular make to be involved in a VRU accident. It would be interesting to compare these figures with European vehicle ownership and mileage to test this hypothesis.

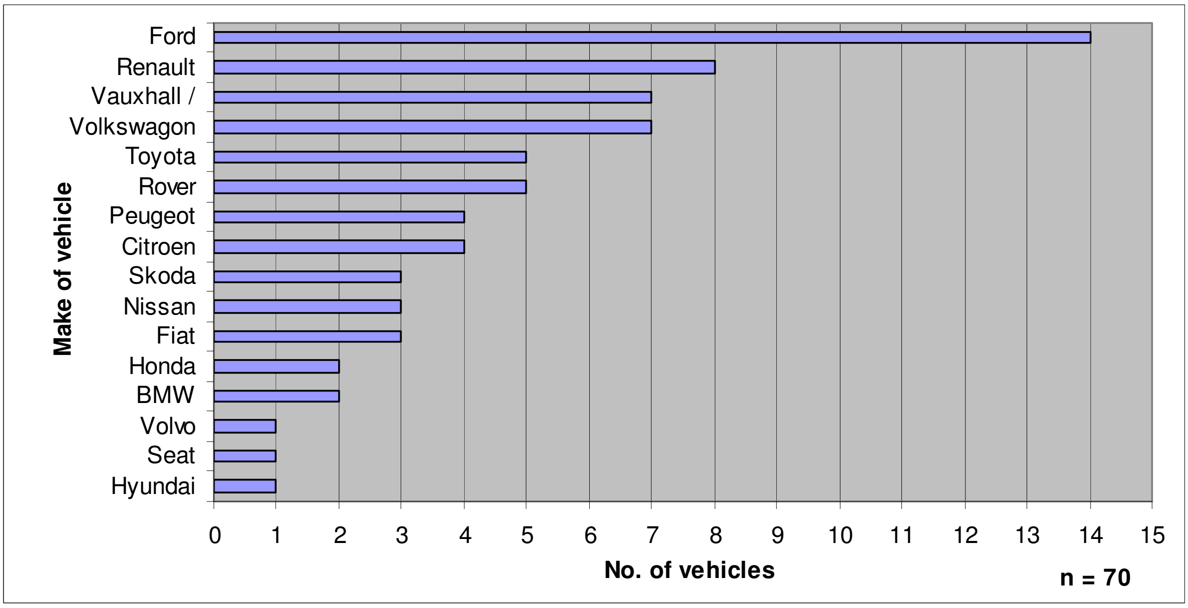

Chart 9 – In-depth sample: Make of vehicle

The year-of-manufacture frequency chart shows the distribution of ages of the vehicles involved. Although the average age is relatively low (1995) - mainly a reflection of the age of the European fleet – half of the in-depth cases involve vehicles manufactured in 1997 or later. It would be more useful to reconstruct the newer models and these are also the models which are more likely to have associated EuroNCAP stiffness data.

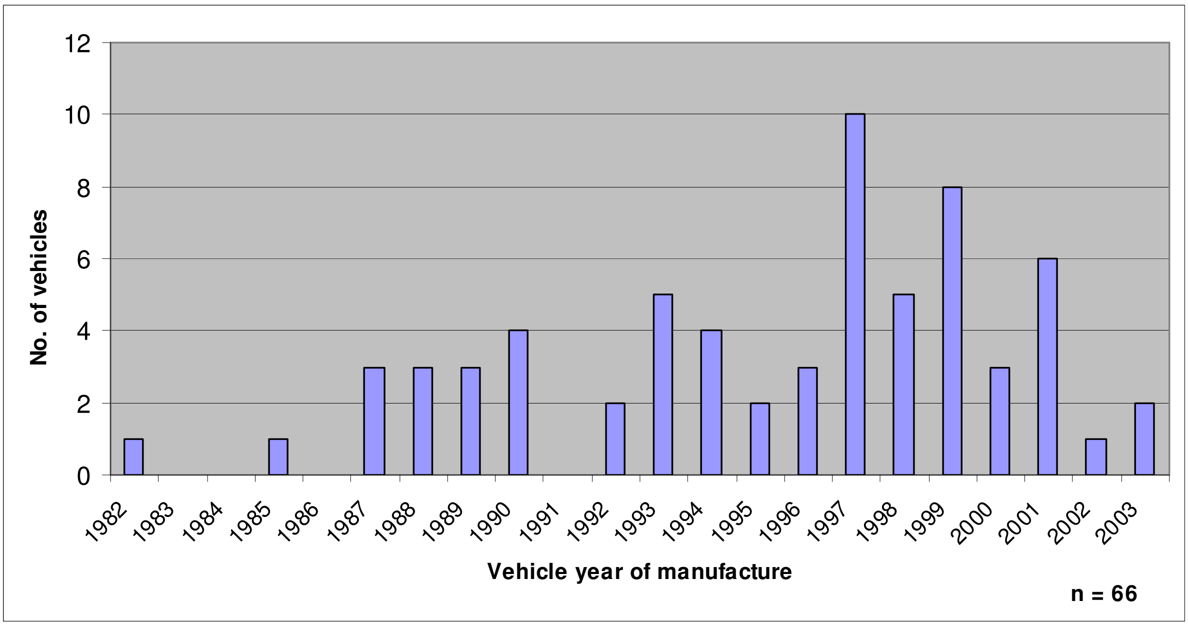

Chart 10 – In-depth sample: Vehicle year of manufacture

3.6 Impact speed

The chart below shows the range of impact speeds found in the in-depth cases.

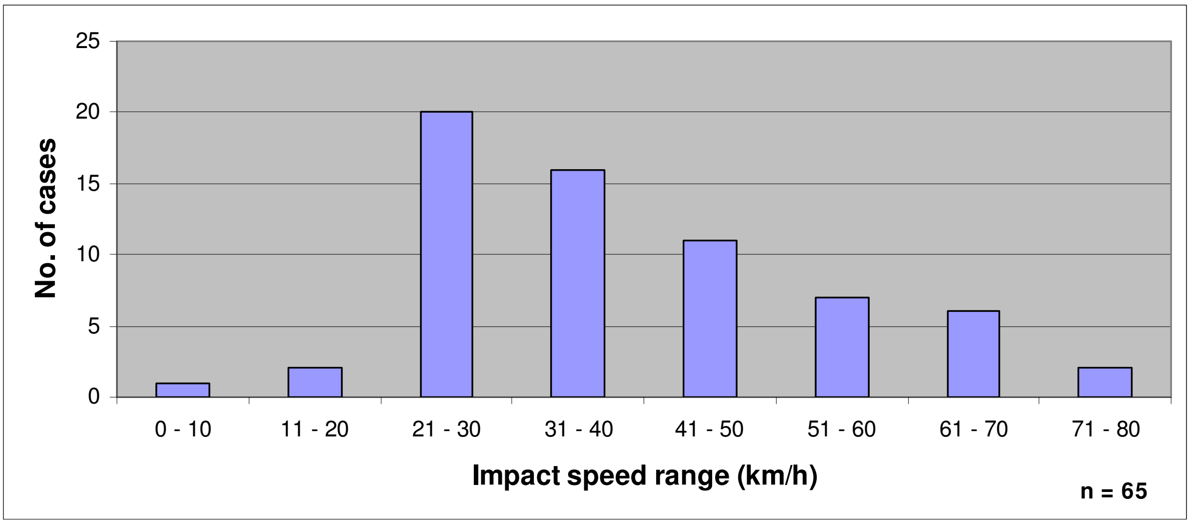

Chart 11 - In-depth sample: Impact speed

Chart 12 below compares the in-depth sample impact speeds with those found in the GIDAS sample. The in-depth sample (mean impact speed of 40km/h) tended to have higher impact speeds then the GIDAS sample (approximate mean impact speed of 28 km/h). This is a consequence of having a disproportionate number of fatal and serious accidents which are more likely to be the result of higher speed impacts.

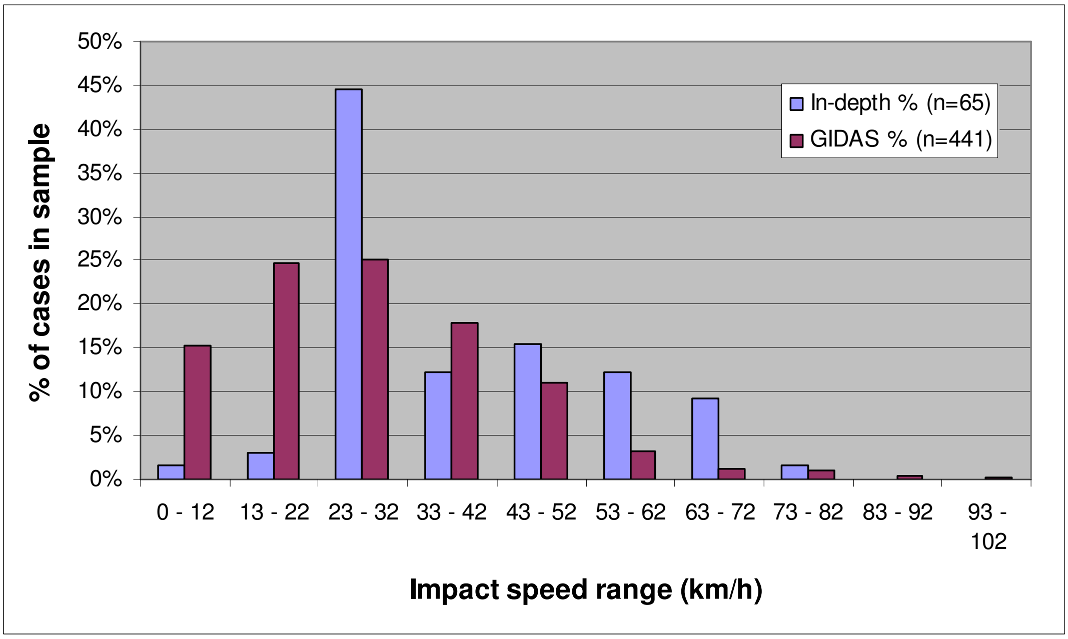

Chart 12 – Comparison with GIDAS[9] data

[9] German In-Depth Accident Study

3.7 Impact speed vs. injury severity

Previous work [3] has established the significant relationship between impact speed and pedestrian injury severity. This relationship is presented for the current study using 3 different definitions of injury severity: fatal / non-fatal, MAIS (Maximum AIS[10]) and ISS (Injury Severity Score).

3.7.1 Fatal and non-fatal accidents vs. impact speed

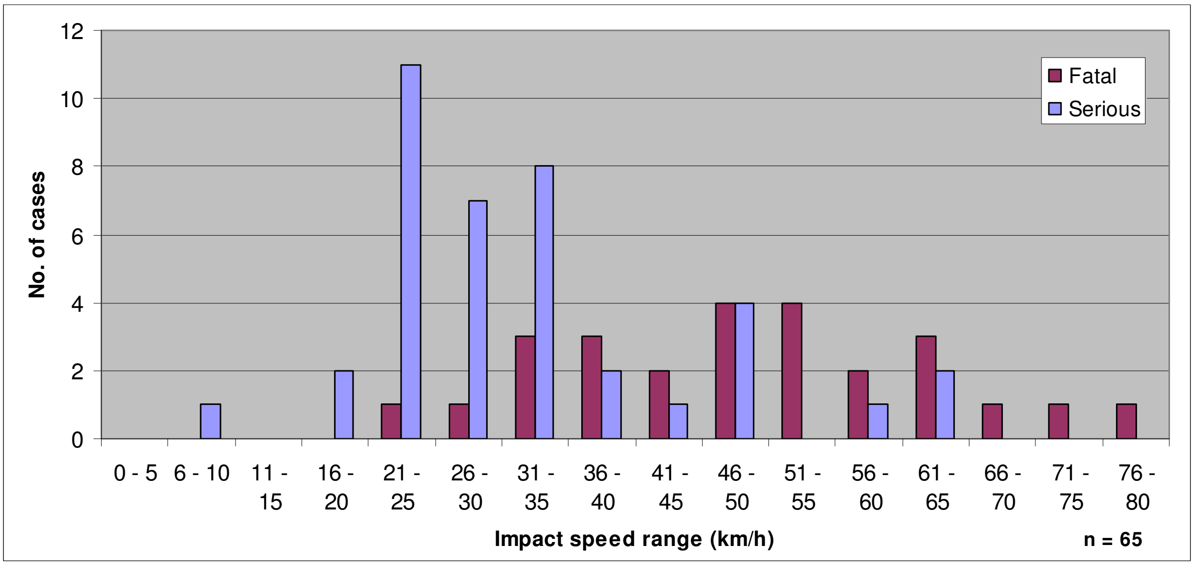

Chart 13 – In-depth sample: Impact speed vs. severity (number)

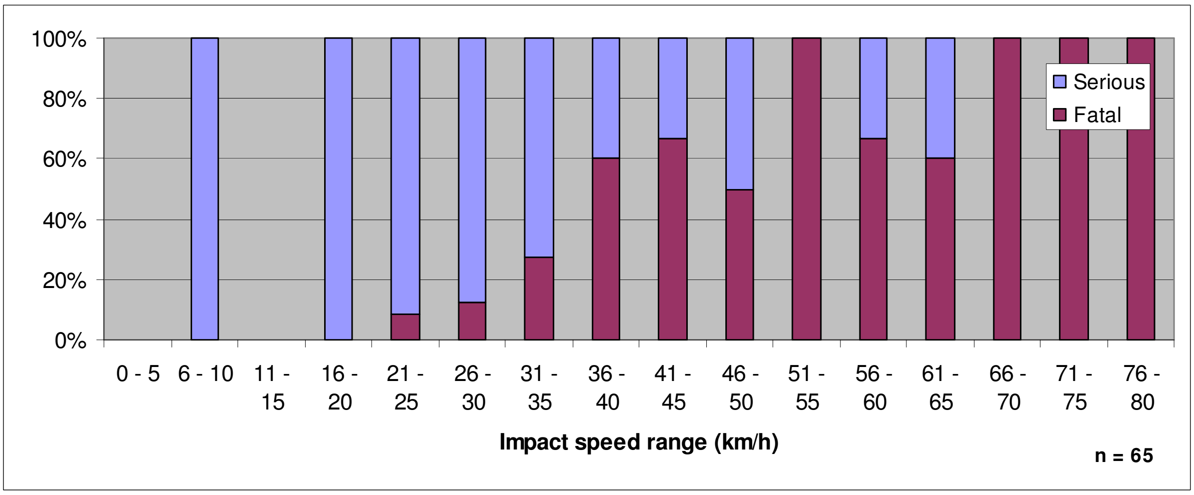

Chart 14 – In-depth sample: Impact speed vs. severity (proportion)

Table 6 – Impact speed vs. severity

	Impact speed (km/h)					% of accidents at ≤ 40km/h
	Mean	**Median**	**Min**	**Max**	**SD**	
Serious (n=39)	32.6	30.0	8.0	64.4	12.1	79%
Fatal (n=26)	49.3	49.1	25.0	75.6	13.3	31%

The difference between the mean impact speeds for serious and fatal accidents is 16.7km/h. This difference is highly significant (p<0.01).

[10] Abbreviated Injury Score

The approximate predicted proportion of serious accidents occurring at impact speeds of less than 40km/h is 0.79 ± 0.13 at a 95% confidence level ($p<0.05$).
The approximate proportion of fatal accidents occurring at impact speeds of less than 40km/h is 0.31 ± 0.18 at a 95% confidence level ($p<0.05$). The difference between these proportions is highly significant ($p<0.01$).

3.7.2 MAIS vs. impact speed

Table 7 – Impact speed vs. MAIS (n=65)

MAIS	Impact speed (km/h)					Accidents at ≤ 40km/h (%)
	Mean	Median	Min	Max	SD	
2 (n=24)	30.3	28.0	20.0	56.3	9.0	88
3 (n=23)	44.8	49.0	8.0	70.8	16.8	39
4 (n=7)	46.3	40.2	22.5	75.6	17.1	57
5 (n=11)	42.8	41.0	27.4	62.8	10.3	46
2-3 (n=47)	37.4	32.2	8.0	70.8	15.1	64
4-5 (n=18)	44.1	40.6	22.5	75.6	13.4	50

The difference between the mean impact speeds for MAIS 2-3 accidents and MAIS 4-5 accidents is 6.7km/h. This difference is not significant ($p>0.05$).

88% of MAIS 2 accidents occurred at speeds of less than or equal to 40 km/h. To extend this to the population with a 95% confidence level, the proportion of MAIS 2 accidents occurring at speeds ≤ 40km/h would be approximately between 75% and 100% ($p<0.05$). Significantly less MAIS 3 accidents (only 39%) occurred at impact speeds of <= 40km/h as would be expected, but the proportion of MAIS 4-5 accidents occurring at or below 40km/h was higher than expected at 50%. This demonstrates the poor correlation between MAIS and impact speed, particularly at higher MAIS values.

Due to the low number of MAIS 4 accidents, both MAIS 4 and MAIS 5 accidents are presented together in the following chart. Values are the percentage of cases with known impact speed (n=65) with each MAIS value or range of values as stated. For example, the light pink bars show the proportion of MAIS 2 cases which fall into each impact speed range. The majority (63%) of MAIS 2 cases were at impact speeds of between 21 and 30km/h. Less conclusively, 80% of MAIS 3 cases and 89% of MAIS 4-5 cases involved impact speeds of over 30 km/h. The MAIS 2 distribution in the chart appears to be more 'normal' and has a relatively low dispersion (SD=9) whereas MAIS 3 and MAIS 4-5 do not demonstrate a normal distribution curve and have significantly higher SD of 16.8 and 13.4 respectively (as shown in Table 7 above).

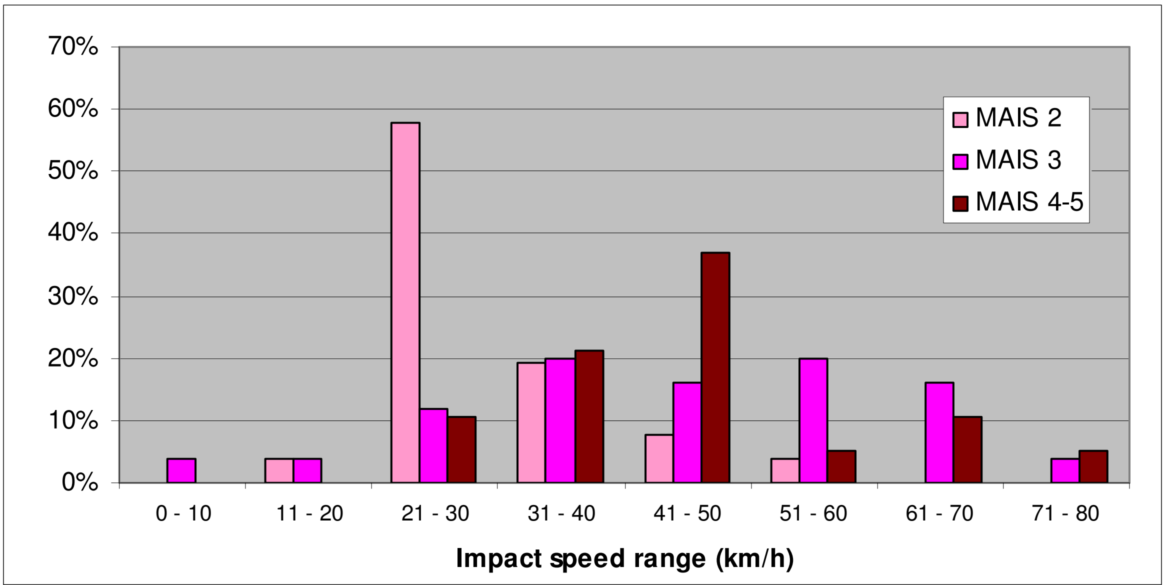

Chart 15 – Impact speed vs. MAIS (% of cases with known impact speeds)

3.7.3 ISS vs. impact speed

The Injury Severity Score (ISS) was presented in 1974 [4] as a method of numerically describing the overall injury severity of patients with injuries to more than one area of the body. The study conducted found that additional (less severe) injuries had a significant effect on mortality and that the proposed ISS scoring had a more linear relationship with mortality than the relationship between mortality and MAIS. The ISS is equal to the sum of the squares of the highest AIS score from the 3 most severely injured body regions. It could be argued that since pedestrian fatalities in particular are often caused by multiple injuries as opposed to one single injury, ISS would be a more meaningful representation of the severity of such accidents. In order to test this theory with respect to the current study, the relationship between ranges of ISS scores and their corresponding impact speed was observed (chart 16). It should be noted that for some of the cases, one or more of the injuries have been assigned an AIS 9 severity code (unknown severity due to insufficient detail) – since ISS cannot be calculated for these cases, there are significantly less ISS values than MAIS values[11].

Table 8 - Impact speed vs. ISS (n=53)

ISS	Impact speed (km/h)					Accidents at ≤ 40km/h (%)
	Mean	Median	Min	Max	SD	
0 – 10 (n=24)	32.8	28.0	8.0	64.4	13.6	75
11 – 20 (n=14)	42.2	38.5	20.0	75.6	16.8	50
> 20 (n=15)	45.3	48.3	22.5	70.8	13.4	27

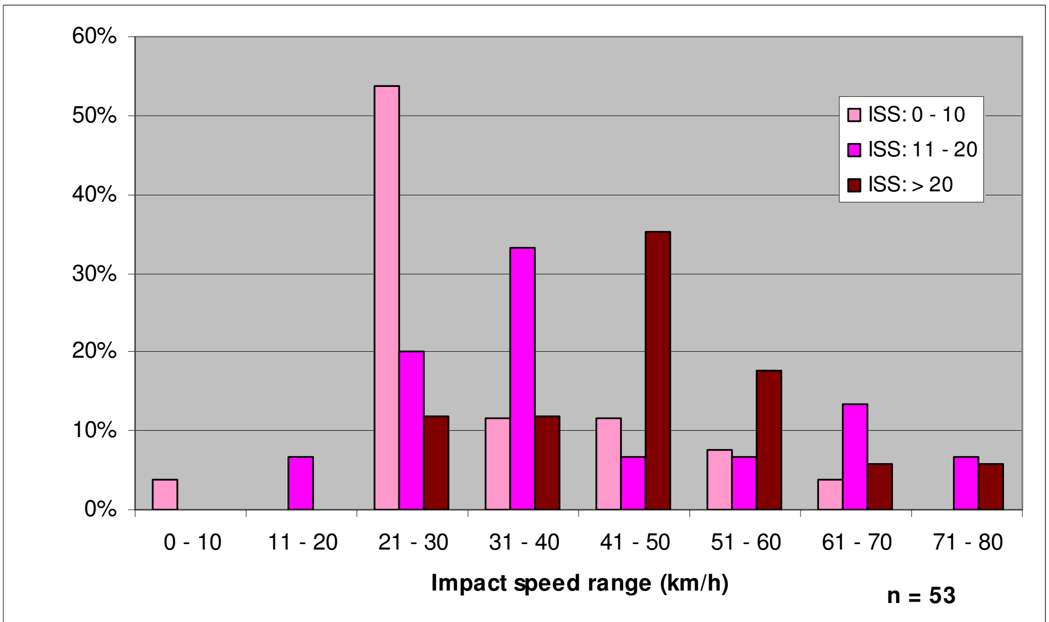

Chart 16 – Impact speed vs. ISS

Looking at each ISS range on the chart, more normal distributions can be seen compared with those for MAIS in chart 15. Table 8 also highlights the more linear relationship between impact speed and ISS when comparing with Table 7. Both the mean impact speed and the percentage of accidents at <= 40 km/h increase fairly linearly with increasing ISS as shown in the tables below:

Table 9 – Comparison of ISS and MAIS

ISS	Mean impact speed (km/h)	Accidents at ≤ 40km/h (%)	MAIS	Mean impact speed (km/h)	Accidents at ≤ 40km/h (%)
0 – 10 (n=24)	32.8	75	**2 (n=24)**	30.3	88
11 – 20 (n=14)	42.2	50	**3 (n=23)**	44.8	39
> 20 (n=15)	45.3	27	**4-5 (n=18)**	44.1	50

[11] All cases have MAIS values but only 58 have ISS values.

3.7.4 Probability of injury vs. impact speed

Chart 17 shows a comparison between injury severity and impact speeds for pedestrian injuries from studies spanning 26 years, from Ashton and Mackay [5], Anderson [6], Hannover [7] and now the current study (APROSYS 2005). The curves drawn are for the relationship:

$$\text{Probability of Injury} \propto V^3$$

from [8], where it is shown that pedestrian injuries can be correlated with impact speed using the concept of Peak Virtual Power.

The trends in the data show that the APROSYS results correlate well with the previous results for serious injuries. For fatal injuries, the APROSYS results are closer to the Hannover results for 2001, indicating that the impact speed for fatalities may be increasing slightly compared to that for the data from 1979 and 1995.

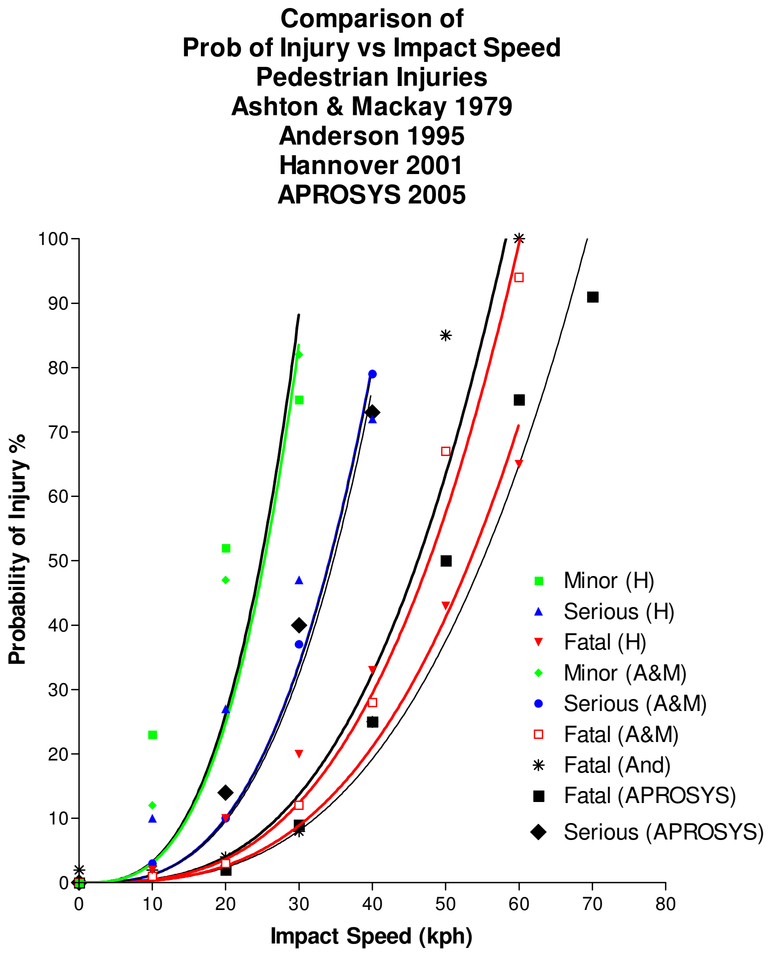

Chart 17 - Probability of injury vs. impact speed

3.8 Vehicle braking

Table 10 – In-depth sample: vehicle braking (n=62)

	No. of cases (%)
Hard braking	10 (16)
Some braking	26 (42)
No braking	26 (42)

The braking behaviour of vehicles in the sample is presented in Table 10. This can be compared with the braking deceleration found in the GIDAS database (Chart 18):

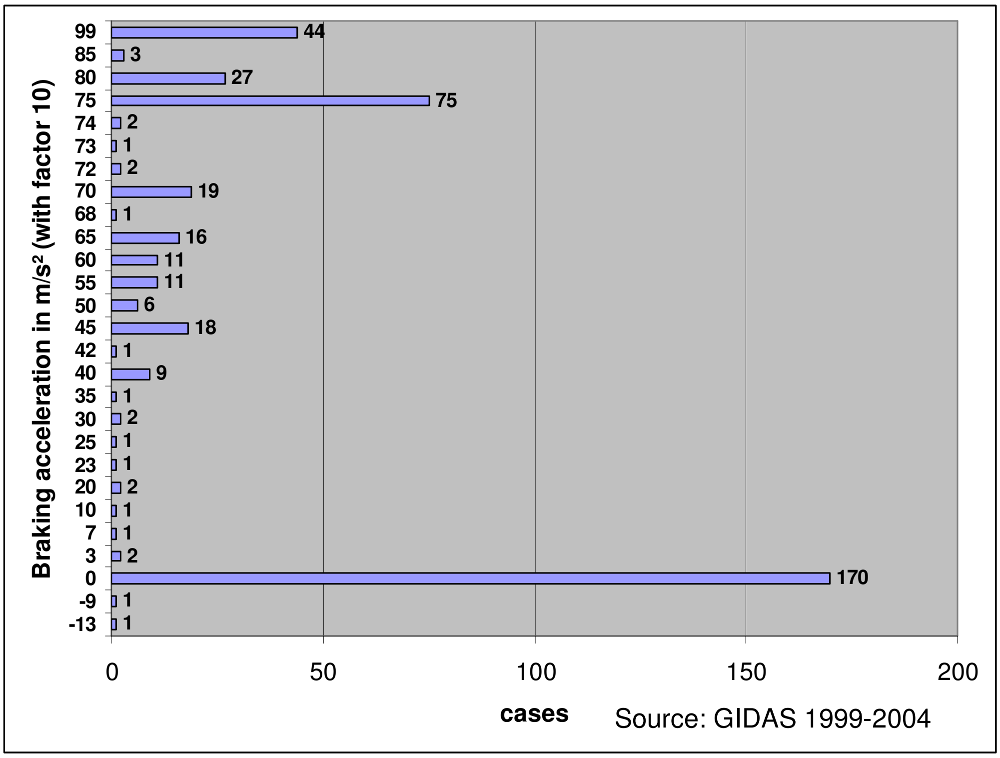

Chart 18 - GIDAS data: Vehicle braking

Table 11 – In-depth sample: braking vs. impact speed (n=58)

	Mean impact speed (km/h)	SD
No braking (n=26)	40.8	17.2
Braking (n=32)	38.4	13.4

There were 59 cases for which both impact speed and pre-impact braking was recorded. One case was removed from this study as an outlier (impact speed of 8km/h with no braking).
However, the difference between the means is still only 2.4km/h which is statistically insignificant.

3.9 Detailed injuries

Although it would be interesting to compare the number of injuries sustained per accident with parameters such as impact speed and age, it must be recognised that the number of injuries recorded in the database are simply that – the number of injuries recorded – and not necessarily the actual number of injuries. Some individual cases have clearly recorded every last superficial injury while some only recorded the main injuries. The variation in the number of recorded injuries per case for each of the different data sources can be seen in Chart 19. Although the number of injuries recorded per case did vary for different data sources, for those with sufficient sample sizes for comparison (i.e. BASC and OTS), there was no significant difference found between the mean no. of injuries per case suggesting that a similar level of detail was used when recording injuries. ISS values were also compared between VRU type, data source and gender (NB: twelve of the cases did not have an ISS value due to one or more of the injuries having an AIS 9 severity – nine of these were from INSIA).

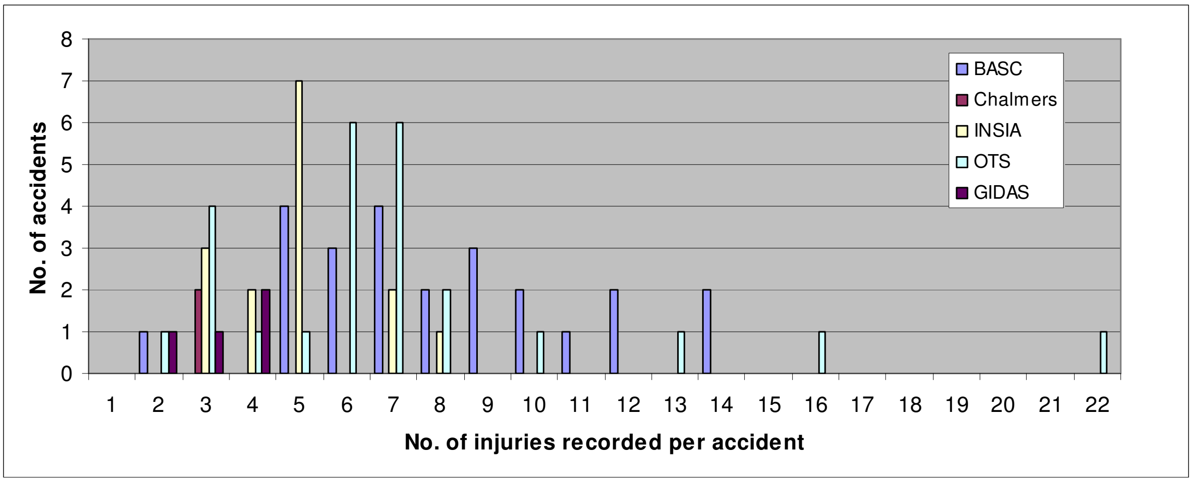

Chart 19 - No. of injuries per case for different data sources

Table 12

Data source (n=70)	**Injuries / case**		**ISS** (n=58)	
	Mean	**SD**	**Mean**	**SD**
BASC (n=24)	8.1	3.0	21.5	10.3
OTS (n=25)	7.1	4.4	11.4	10.5
INSIA (n=15)*	4.9	1.5	8.7	5.7
GIDAS (n=4)	3.3	1.0	8.3	3.2
Chalmers (n=2)	3.0	0.0	19.0	2.8

*only 6 INSIA cases had ISS values

Table 13

Gender (n=67)	**Injuries / case**		**ISS** (n=58)	
	Mean	**SD**	**Mean**	**SD**
Male (n=39)	6.5	4.0	14.4	10.9
Female (n=28)	6.9	3.1	16.7	11.2

Table 14

VRU type (n=70)	**Injuries / case**		**ISS** (n=58)	
	Mean	**SD**	**Mean**	**SD**
Pedestrian (n=63)	6.7	3.5	15.9	10.9
Cyclist (n=7)	6.0	4.0	8.4	8.2
Cyclist (n=6)*	4.7	2.2	5.3	0.5

* removing the fatal cyclist accident outlier (BC001)

3.10 Injury severity

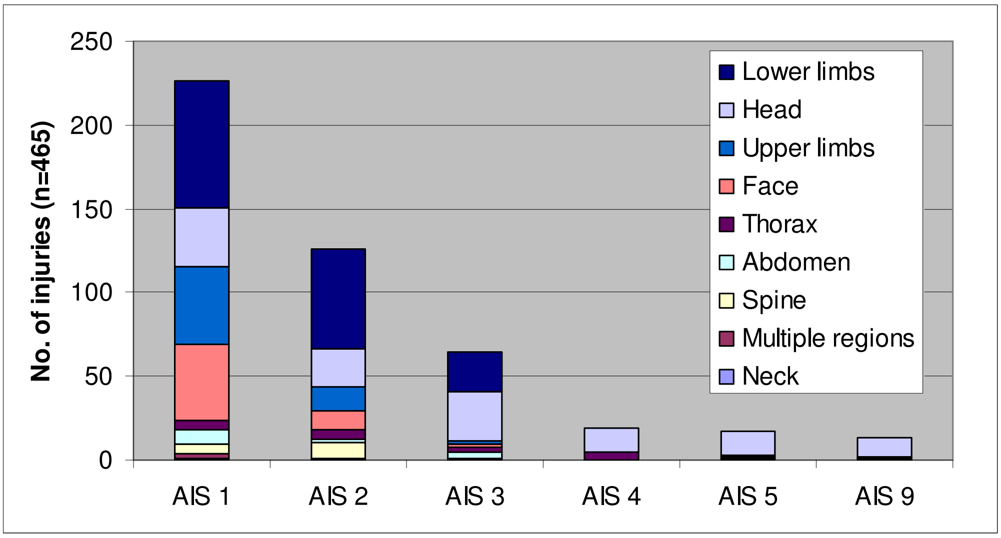

Chart 20 - No. of injuries at each level of severity[12]

Table 15 – Gender vs. severity

Gender	Minor injuries (AIS 1, 2)	Serious injuries (AIS 3+)	All injuries[13]
Male (n=39)	198 (78%)	49 (19%)	254
Female (n=28)	137 (71%)	50 (26%)	193
Unknown (n=3)	17 (94%)	1 (6%)	18
Total (n=70)	352 (76%)	100 (22%)	465

According to both AIS values (table 12) and ISS values (table 15), the females in the sample tended to have more serious injuries but this could be due to do with the fact that a higher proportion of VRUs over the age of 60 were female (see chart 4).

Table 16 – VRU type vs. severity

VRU type	Minor injuries (AIS 1, 2)	Serious injuries (AIS 3+)	All injuries[13]
Pedestrian (n=63)	316 (75%)	94 (22%)	423
Cyclist (n=7)	36 (86%)	6 (14%)	42

According to both AIS values (table 16) and ISS values (table 14), cyclist injuries tended to be less serious although the sample size is too small to make inferences about the population.

[12] AIS 9 means unclassified severity

[13] Including AIS 9 injuries

3.11 Injury severity by body region

The following cross-tabulation on all injuries recorded in the database (n = 465) compares the injured body region with the associated AIS severity value.

Table 17 – AIS body region and severity

	AIS Injury Severity – No. of injuries						
	Slight		Serious			Unclassified	Body region total (%)
	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 9	
Head	35	22	30	14	14	11	126 (27.1)
Face	45	11	1	0	0	0	57 (12.3)
Neck	1	0	0	0	0	0	1 (0.2)
Thorax	6	6	3	5	1	1	22 (4.7)
Abdomen	9	2	4	0	1	1	17 (3.7)
Spine	5	9	1	0	1	0	16 (3.4)
Upper limbs	47	15	2	0	0	0	64 (13.8)
Lower limbs	75	60	23	0	0	0	158 (34.0)
Multiple regions	3	1	0	0	0	0	4 (0.9)
AIS severity total (%)	226 (48.6)	126 (27.1)	64 (13.8)	19 (4.1)	17 (3.7)	13 (2.8)	465 (100)

The most frequently injured body regions are the head and lower limbs. However, a higher proportion of the head injuries are AIS 3+ compared with the lower limb injuries. In AIS and consequently in the current study, the face is treated as a separate body region - the head and face injuries combined would outnumber the lower limb injuries. In a similar earlier study done at Hannover (Chart 22) [9] on accidents from 1985 - 1995, facial injuries are considered together with head injuries but the Lower limbs are separated into Pelvis, Upper Leg, Knee, Lower Leg and Foot – here, the combined lower limb injuries outnumber the head injuries. The different relative proportion of injuries to the head and to the lower limbs (after accounting for the different definitions) could be explained by the influence of the changing shape of vehicles since the earlier study. There could also be a slight influence on these proportions from the over-representation of fatal accidents in the current study.

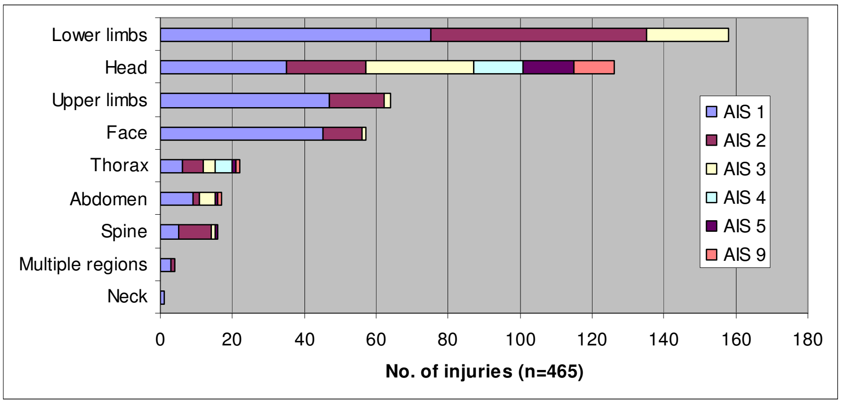

Chart 21 – Injuries per body region (In-depth database 1997 - 2004)

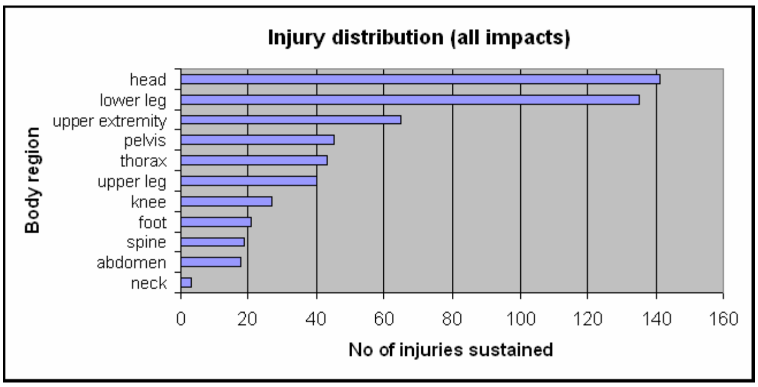

Chart 22 – Injuries per body region (Hannover data [9]: 1985 - 1995)

3.12 Head injury

As one of the most frequently and seriously injured body regions, head injuries were studied separately. 49 out of the 70 VRUs suffered some kind of head injury and a total of 126 injuries to the head were coded – on average 2.5 coded injuries per injured head. The amount of detail available varied according to the source as shown in Table 18. Hospitals often report head injury with no further details making it impossible to know the severity and therefore ascertain an ISS value for the injured party. This is never the case for post mortem reports which also give more specific injuries to describe the injury to the head - however, those who are fatally injured would be more likely to have sustained more individually definable injuries so it is difficult to know which factor is more significant. As expected, cases involving an AIS 4+ head injury were more likely to be fatal, as were those involving a skull fracture (Table 19). Table 20 shows all the recorded head injuries (n=126) grouped by type according to the AIS 90 [10] codes.

Table 18 – Depth of head injury data available: comparison of data source[14]

Main injury data source (n=67)	No. of VRUs with head injury	No. of fatalities[15]	Mean no. of coded injuries to the head	No. of cases with AIS 9 head injury
Hospital	29	7	2.3	11
Post mortem	17	16	3.3	0

Table 19 – Head injury analysis for different outcomes

Overall severity (n=49)	No. of VRUs with head injury	Mean no. of coded injuries to the head	Mean MAIS for head region (n=38)	Cases with AIS 4+ head injury	Cases with skull fracture
Fatal[15]	23	3.0	3.4	9 (39%)	12 (52%)
Serious	26	2.2	2.6	6 (23%)	4 (15%)

Table 20 – Analysis of detailed head injury definitions

Region	Injury descriptor	No. of injuries	No. of injuries per region (%)
NFS	Head injury - NFS[16]	11	26 (21%)
	Loss of consciousness (LOC)	15	
Scalp	Scalp abrasion	19	39 (31%)
	Scalp contusion	17	
	Scalp laceration	3	
Cranial nerves	Cranial nerve injury	1	1 (1%)
Skull	Skull fracture (vault)	9	18 (14%)
	Skull fracture (base)	9	
Brain stem	Brain stem injury	3	3 (2%)
Cerebellum	Cerebellum injury	4	4 (3%)
Cerebrum	Cerebral injury - NFS	2	35 (28%)
	Cerebral contusion	8	
	Diffuse axonal injury	3	
	Cerebral haematoma - NFS	1	
	Extradural haematoma	2	
	Intracerebral haemorrhage	2	
	Subdural haematoma	9	
	Brain swelling / oedema	2	
	Intraventricular haemorrhage	1	
	Subarachnoid haemorrhage	5	

[14] For 3 of the cases, the injury data source was not provided

[15] Fatality defined as dying as a result of accident within 30 days

[16] Not Further Specified

3.13 Head impact location

The locations of head impacts for all the cases were plotted schematically on one standard vehicle – similar to Figure 8 of Otte's 1999 IRCOBI paper [11]. Head impact locations have been plotted in their relative positions as opposed to absolute positions for the sake of comparing accidents involving different shaped vehicles (i.e. a head impact occurring on the top left corner of the windscreen will be shown on the top left corner of the windscreen in the diagram regardless of the WAD[17]).

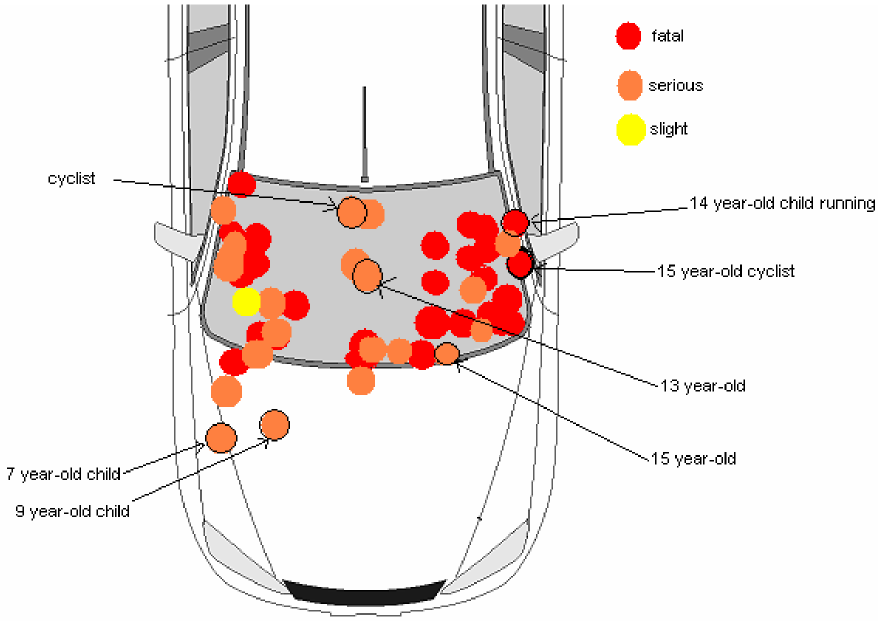

Figure 1 – Head impact locations by severity

As shown in Figure 1, the fatal head impacts occurred predominantly on and around the windscreen frame (A-Pillars and scuttle). The only impacts occurring in the centre of the windscreen were non-fatal. Of the 3 head impacts occurring on the bonnet away from the scuttle, all were non-fatal and 2 were children.

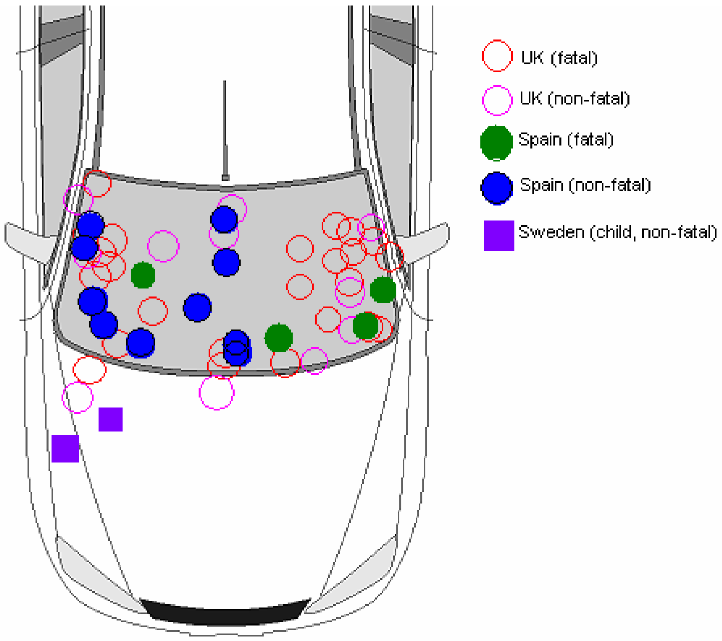

Figure 2 – Head impact locations by severity and country.

[17] Wrap Around Distance

The head impact positions were also plotted and coloured according to which country the accident occurred in the see if impacts occurred on a certain side for left–hand and right-hand drive countries respectively - i.e. right-hand drive for UK, left-hand drive for Mainland Europe (Spain and Sweden) (Figure 2).
UK head impacts: 5 on centre-line, 13 on right, 17 on left
Mainland Europe head impacts: 4 on centre-line, 9 on right, 3 on left

It is interesting to compare these with a similar schematic showing the results of a selection of EuroNCAP tests on various sites around the windscreen for a selection of vehicles. Unfortunately tests were not carried out on locations further away from the windscreen frame.

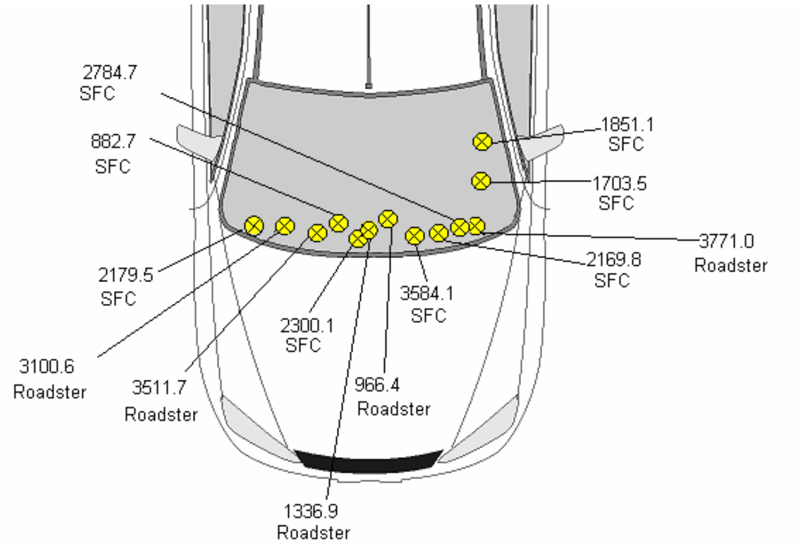

Figure 3 – Selection of EuroNCAP test site HIC[18] results for SFC[19] and Roadsters

Perhaps more comparable are the results of a previous study by Mizuno [12] which involved headform impact tests on and around the windscreen:

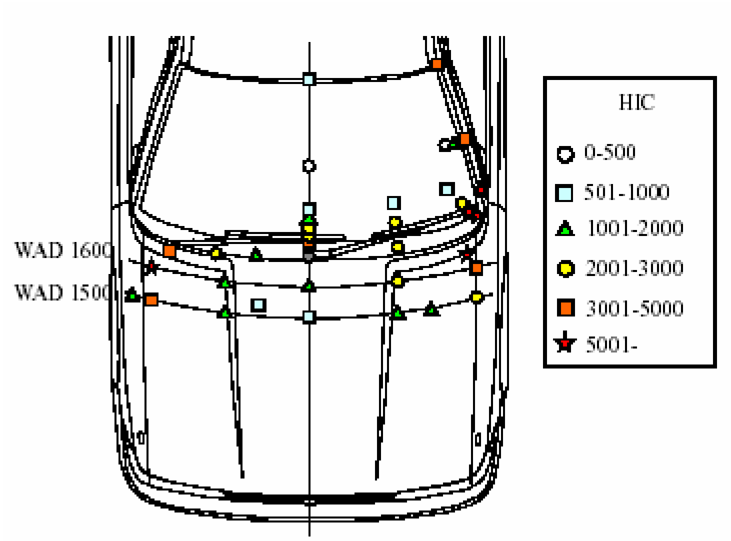

Figure 4 - HIC distributions and impact location by impact position for the tested car (40 km/h) [12].

[18] Head Injury Criterion

[19] Small Family Car

4. Discussion

The in-depth database of pedestrian and cyclist developed for the reconstruction activity was analysed to assess whether or not it was representative of the European epidemiology. Data for which a reasonably direct comparison was possible included type, age and gender of the vulnerable road user, road conditions, time of day and also the relationship between age and severity. Cyclists were not well represented – only 7 cases were available which allowed few conclusions to be drawn about the characteristics of cycling accidents or injured cyclists. The younger age ranges (under 30) were represented in proportion with the epidemiology but the older age ranges were slightly over-represented (explained by the BASC contribution of all-fatal accidents and the higher proportion of older people in this category), male and female were well represented, wet or damp road conditions were slightly under-represented, the time of day chart showed a morning and afternoon peak similar to the epidemiology, but the morning peak was slightly earlier and the afternoon peak later and more pronounced. As previously mentioned, fatal accidents were over-represented due to the information source available. When comparing age and severity, the general trend of increased age leading to increased risk of fatality could be seen to some degree in Charts 7 & 8. The difference in mean age of those seriously injured and those fatally injured was found to be statistically significant (Table 5). An assessment of the vehicles represented by the sample was more reflective of the fleet than any prevalence for a particular year of manufacture or make of vehicle to be involved in a VRU collision. The average year of manufacture was 1995 but half the vehicles were 1997 or later.

On further analysis, more information on the characteristics of pedestrian and cyclist accidents not provided by the epidemiology was obtained: The standing orientation of the pedestrian prior to impact was 89% stuck side-on – which agreed with the literature [2]. The in-depth sample impact speeds were presented and compared with those found in the GIDAS sample (Chart 12). The former tended to have higher impact speeds than the latter (mean of 40km/h and 28km/h respectively) - a consequence of having a disproportionate number of fatal and serious accidents which are more likely to be the result of higher speed impacts. The relationship between impact speed and injury severity was presented using 3 different definitions of injury severity: fatal / non-fatal, MAIS (Maximum AIS) and ISS (Injury Severity Score). The difference between the mean impact speeds for serious and fatal accidents was highly significant. The MAIS vs. impact speed relationship, presented and discussed in detail in the main section, was found to be quite non-linear when comparing the progression of both mean impact speed and percentage of impact at <= 40 km/h with increasing MAIS (table 7). As expected, a better relationship was found between ISS and impact speed due to better suitability of this description of injury severity to the multiple injury nature of VRU accidents. There is a good correlation between the injury risk curves for serious injuries vs. impact speed derived from the current study and those from similar studies. For fatal injuries, the APROSYS results are closer to the 2001 study [7], indicating that the impact speed for fatalities may be increasing slightly compared to that for the data from 1979 [5] and 1995 [6]. The mean impact speed of vehicles which braked before impact and those which didn't was compared but no significant difference was found.

For each case, detailed injuries were recorded (total n=465). This provided a good sample size for assessing typical body regions and corresponding severities of VRU injuries. Cyclists had on average fewer injuries than pedestrians and their injuries were of lower severity – however, with such a small sample size (only 7 cyclist cases) this is not statistically significant. Lower limb injuries were most common followed closely by head injuries. Facial injuries were considered separately according to AIS protocol – if considered as one body region, the most common injury region would be the head. Also interesting to note is that out of 465 injuries, only 1 was to the neck, AIS 1. Looking at AIS 4 - 5 injuries only, the thorax is the next most significant region after the head, but including AIS 3 injuries, the upper limbs become the next most significant region after the head, followed by the thorax. The head injuries were studied in more detail and the depth of information from different sources was compared with post mortem records yielding the best quality head injury data. 49 of the cases involved head injury – with a total of 126 head injury definitions (an average of 2.5 injury codes per injured head). The different types of head injury were presented and also grouped into physical region. 31% of head injuries were to the scalp, 28% involved the cerebrum, 14% were skull fractures and 15% were LOC.

The head impact locations for all impacts were plotted schematically on one generic vehicle diagram, showing the positions of primary head impact relative to the windscreen, scuttle and A-Pillars for fatal and non-fatal impacts (Figure 1). The fatal head impacts occurred predominantly on and around the windscreen frame (A-Pillars and scuttle). The only impacts occurring in the centre of the windscreen were non-fatal. Of the 3 head impacts occurring on the bonnet away from the scuttle, all were non-fatal and 2 were children. The head impact positions were also plotted and coloured according to which country the accident occurred in the see if impacts occurred on a certain side for left–hand and right-hand drive countries respectively - i.e. right-hand drive for

UK, left-hand drive for Spain and Sweden (Figure 2). All 13 non-fatal head impacts in Spain and Sweden were located on or to the right of the windscreen centre-line, but the 3 remaining Spanish fatal head impacts did occur on the left side. The UK head impacts had only a slight skew towards the left side of the windscreen centre-line. Together, this does suggest that in countries where vehicles drive on the left, head impacts are more likely to occur on the left and in countries where vehicles drive on the right, head impacts are more likely to occur on the right. In other words, head impacts are slightly more common on the nearside of the vehicle.

The information revealed by the analysis of the detailed accident database, together with the results from the accident reconstruction from Task 3.2.3, will be utilised by WP3.3 (Test Methods) in considering the need for new or amended vehicle assessment techniques, to take into account the injuries sustained by vulnerable road users in real world accidents and under real world accident scenario conditions.

The data from the analysis may also be helpful to SP2 and SP4 to complement their own accident data and to SP7 for their activities in tasks 7.2 and 7.4.

5. Conclusions

1. Analysis of the In-depth accident database revealed that in most areas it was representative of the European epidemiology.
2. The analysis generated more information on the characteristics of pedestrian and cyclist accidents than was provided by the epidemiology – this information will be very useful in the later activities of the Pedestrian and Cyclist Accidents sub-project in APROSYS.
3. Cyclists were under-represented in the database, making it impossible to draw definitive conclusions on the characteristics of cyclist accidents or injured cyclists.
4. The majority (89%) of pedestrians were struck side on (in agreement with the literature).
5. A better relationship was found between ISS (Injury Severity Score) and impact speed than between MAIS and impact speed, due to better suitability of this description of injury severity to the multiple injury nature of VRU accidents.
6. There was a good correlation of injury risk as related to impact speed between the cases in the In-depth database and previously published studies.
7. The most frequently injured body regions were the head and lower limbs but head injuries tended to be more serious.
8. Post mortems yielded better quality head injury data than hospital records.
9. Involvement of an AIS 4+ head injury or a skull fracture in the sample were both associated with a higher risk of fatality than less severe head injuries or absence of skull fracture respectively.
10. The locations of primary head impacts were presented schematically and lay principally on the windscreen, scuttle and A-pillar. Child head impacts were specifically identified with teenager head impacts lying in the same regions as adults and children under 10 impacting nearer the centre of the bonnet.
11. Head impacts were identified as being more common on the nearside of vehicles (that is, nearest to the kerb) regardless of whether the vehicles were left or right hand drive.

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