

## European project AsPeCSS - interim result: Development of Test Scenarios based on identified Accident Scenarios

**Marcus Wisch, Patrick Seiniger**

Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt)  
Germany

**Mervyn Edwards**

Transport Research Laboratory (TRL)  
Great Britain

**Thomas Schaller**

BMW Group  
Germany

**Mònica Pla, Andrés Aparicio**

Applus IDIADA Group  
Spain

**Stéphane Geronimi**

PSA  
France

**Nils Lubbe**

Toyota Motor Europe  
Belgium

Paper Number 13-0405

### ABSTRACT

Within this paper different European accident data sources were used to investigate the causations and backgrounds of road traffic accidents with pedestrians. Analyses of high level national data and in-depth accident data from Germany and Great Britain was used to confirm and refine preliminary accident scenarios identified from other sources using a literature review. General observations made included that a high proportion of killed or seriously injured pedestrian casualties impacted by cars were in 'dark' light conditions.

Seven accident scenarios were identified (each divided into 'daylight' and 'dark' light conditions) which included the majority of the car front-to-pedestrian crash configurations.

Test scenarios were developed using the identified accident scenarios and relevant parameters. Hypothetical parameters were derived to describe the performance of pedestrian pre-crash systems based on the assumption that these systems are designed to avoid false positives as a very high priority, i.e. at virtually all costs. As result, three 'Base Test Scenarios' were selected to be developed in detail in the AsPeCSS project. However, further Enhanced Test Scenarios may be needed to address environmental factors such as darkness if it is determined that system performance is sensitive to these factors.

Finally, weighting factors for the accident scenarios for Europe (EU-27) were developed by averaging and extrapolation of the available data.

This paper represents interim results of Work Package 1 within the AsPeCSS project.

### INTRODUCTION

#### Background

In 2009, 6,641 pedestrians were killed in road traffic accidents in the EU-24<sup>1</sup>, which is about 20% of all fatalities. This equates to an average rate of 13.6 pedestrians killed per million inhabitants, which varies by member state from the lowest of 3.8 pedestrians killed per million inhabitants in the Netherlands to the highest of 47.2 in Romania. In 2009, nearly half (46%) of all pedestrian fatalities in the EU-24 states occurred during dark light conditions (varying between 94% in Ireland and 35% in France) and another 6% in twilight [1].

The German national road traffic statistics show that in the year 2008, 653 pedestrians were killed in Germany, but this number had fallen to 476 in 2010. This was the lowest value since the start of the statistical recordings. However, this number had again risen to 614 in 2011. The number of 614 killed pedestrians was accompanied by 8,854 seriously injured and 27,542 slightly injured pedestrians. In addition, the accident statistics report that in case of pedestrian fatalities older people (65+ years) constitute to nearly half, which

---

<sup>1</sup> Data available from member states of the European Union EU-27 without Bulgaria, Cyprus and Lithuania

shows that this group is over-represented for pedestrians [2].

Generally, pedestrians cross streets wherever it is convenient and possible, which is not necessarily at pedestrian crossings. Because of this, EuroTest [3] investigated, by means of national statistics for 2005 for various European countries, the incidence of pedestrian accidents with fatalities on and outside pedestrian crossings. In conclusion, a significant diversity of results was shown for the different countries in combination with no significant correlation to 'rules and directives governing the right of way' or the 'pedestrian crossing planning and design'. However, the major differences in European countries were found to be related to basic elements such as traffic law duties of pedestrians and motorists at pedestrian crossings, the national criminal fines and catalogues and the interpretation of the types of crossings.

An APVRU study [4] evaluated "near miss crashes" and found that the accident risk depends strongly on local situations, the flow of traffic and the crossing facilities. Furthermore, pedestrian inattention was identified as the main causative type of behaviour in case of accidents. Elderly also tend to require more time to cross the road and estimate speeds and distances less accurately.

### **European FP7 project AsPeCSS**

The overall objective of the European FP7 project AsPeCSS (Assessment methodologies for forward looking integrated Pedestrian and further extension to Cyclist Safety Systems) is to contribute towards improving the protection of vulnerable road users, in particular pedestrians and cyclists, through the development of harmonised test and assessment procedures for forward-looking integrated pedestrian safety systems. These procedures will take into account the system's pre-crash braking and passive safety components and will be benefit based. Within Work Package 1 accident scenarios and associated test scenarios with weighting factors have been developed for the assessment of the pre-crash braking component of integrated pedestrian safety systems.

### **Objective**

The objective of the work described in this paper was to identify accident scenarios and develop associated test scenarios for the assessment of the pre-crash braking component of integrated pedestrian safety systems.

### **METHODS AND DATA SOURCES**

To identify accident scenarios results from previous projects (e.g. European FP7 project APROSYS, AEB Test Group, vFSS) were reviewed and further

extensive analysis of national and in-depth car-to-pedestrian accident data from Germany and Great Britain (GB) was performed (note: for full information please see [5]).

The Autonomous Emergency Braking (AEB) Test Group comprises several insurer-funded research centres. Outline test procedures were published by the group in 2011 [6].

The vFSS group ("advanced Forward-looking Safety Systems") was founded to develop technology independent test procedures for primary safety driver assistance systems (in particular advanced emergency braking systems), which reflect the real accident situation. The project consortium consists of several car manufacturers, the German insurance association and BASt.

The German national road traffic statistics cover accidents which were reported to the police. Pursuant to Article 1 of the German law on statistics of road traffic accidents only those accidents are recorded which are due to vehicular traffic, i.e. accidents involving pedestrians only, are not covered by these statistics. Survey records for the statistics of road traffic accidents are the copies of the standard traffic accident notices (Verkehrsunfallanzeigen) as used for the entire Federal Republic which are completed by police officers attending the scene of the accident.

In contrast to this, i.e. recording of all personal injury accidents with a low level of detail, GIDAS (German In-Depth Accident Study) is devoted primarily to the task of documenting a representative sample of individual road traffic accidents with a high level of detail. In this study, GIDAS data from year 2000 to 2011 were used.

STATS19 is the reported road traffic injury accident database in Great Britain, established in 1949. Data is collected in England, Scotland and Wales by police using a standardised STATS19 data gathering form. Police are required to attend every road traffic accident that involves an injury and whilst on scene, officers fill out a series of standard forms. In this study, STATS19 data from 2008 to 2010 were used to determine the proportion of pedestrian casualties in each accident scenario. The number of killed or seriously injured casualties was of particular interest.

Weighting factors to indicate the relevance of the accident scenarios were also calculated for Europe. Finally, test scenarios based on these accident scenarios were developed. This work considered basic physics and contributing factors such as the age of pedestrians, speed data of the parties, societal factors, light and weather conditions. With the novel approach taken it was found that some test scenarios were relevant for a number of accident scenarios.

## Definitions

In this paper ‘darkness’ and ‘dark light conditions’ includes both the darkness and twilight conditions specified in the national databases, unless stated otherwise.

An Accident Scenario is defined as a crash configuration (general motion of vehicle and pedestrian) together with key surrounding conditions (e.g. road layout, view of pedestrian obstructed or not, dark or light).

A Test Scenario is a test configuration which reflects the characteristics of one or more accident scenarios which are key to the performance of the pedestrian safety system.

## ACCIDENT DATA REVIEW

### Results from Previous Projects

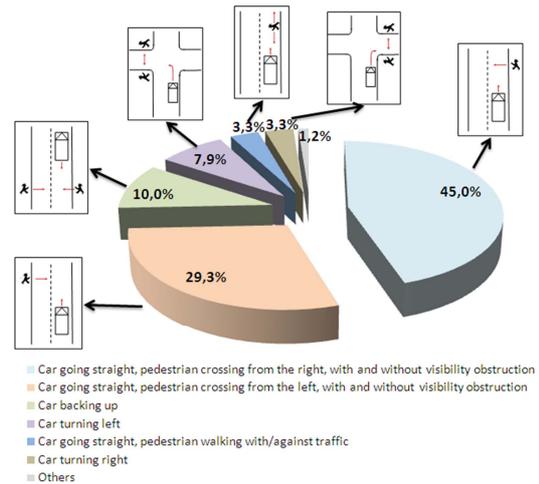
A first estimation for accident scenarios was made based on the results of the work performed by APROSYS, the AEB Test Group and vFSS (for details please see [5]).

The scenarios proposed by the AEB Test Group were defined predominantly by analyses of British collision data (with supplementary analyses of German data). The principal collision data analysis used a cluster analysis technique to identify groups of collisions with similar characteristics. Two separate cluster analyses were performed; the first used the national STATS19 database for Great Britain, and the second used the (in-depth) On-The-Spot (OTS) database. Table 1 shows the key accident scenarios identified within the AEB project for killed, killed and seriously injured (KSI) and all injured pedestrian casualties.

**Table 1: Accident scenarios from AEB project**

No	Accident Scenarios	Description	Representativeness (%)		
			Killed	KSI	All
1		Pedestrian walking; Daylight, fine; vehicle going ahead; 10-30mph speed limit; mid-size pedestrian; crossing especially from near-side; Not obstructed	24	34	39
2		Pedestrian running; Daylight, fine; vehicle going ahead; 10-30mph speed limit; small pedestrian; crossing especially from near-side; obstructed	4	13	14
3		Pedestrian walking; Darkness, not fine; vehicle going ahead; 10-30mph speed limit; large pedestrian; crossing either direction; not obstructed	41	28	21
4		Pedestrian walking; Darkness, fine; vehicle going ahead; mid-size pedestrian; stationary or along; not obstructed	14	5	3
TOTAL			83	80	77

An overview of key scenarios identified by the vFSS project is provided in Figure 1. Lateral crossing scenarios with and without obstructions formed the largest proportions.



**Figure 1: Key accident scenarios identified by the vFSS group [7]**

These results were merged to form preliminary accident scenarios (see Table 2), that served as a basis for further development.

**Table 2: Preliminary Accident Scenarios for AsPeCSS (derived from previous projects)**

ID	Accident Scenario Description
1 A/B	Crossing straight road, nearside, no obstruction, day/dark
2 A/B	Crossing straight road, offside, no obstruction, day/dark
3 A	Crossing at junction, nearside, vehicle turning across traffic, day
4 A	Crossing at junction, nearside, vehicle not turning across traffic, day
5 A/B	Crossing straight road, nearside, obstruction, day/dark
6 A/B	Crossing straight road, offside, obstruction, day/dark
7 A/B	Along straight road, no obstruction, day/dark

## ACCIDENT DATA ANALYSIS

At this point, additional information was needed and thus further investigations were performed using current data from Germany and GB to identify accurately the weighting for the preliminary accident scenarios identified above and to check their appropriateness. It should be noted that French national accident data was also used for the analysis but it is not reported in this paper because it added little to the analysis due to the limited extent of the data. For full information please see [5].

### Results Germany

The analyses of German national accident data were used to identify common accident scenarios of car-to-pedestrian crashes and appropriate weighting factors for them. The analysis involved the identification of all pedestrian casualties involved in crashes with a car and the examination of the characteristics of the target population; in particular to determine the proportion injured in each of the preliminary accident scenarios defined.

Investigation of road traffic accidents with personal injuries involving pedestrians in Germany in 2011

shows that pedestrian accidents mostly occur in urban areas with a share of 94 % (31,168 accidents), rather than non-urban (country) areas (6 %, 1,832 accidents). Table 3 shows the numbers and proportions of injured pedestrians in 2011 with their injury severity (includes multiple counting since one accident can contain multiple road user types). The proportion of pedestrians injured in built-up areas (around 94 % of the total casualties) compared to the proportion killed (69%) indicates that although the greater proportion of accidents occur in built-up areas, the ones that occur in non-built-up areas are more injurious [2].

**Table 3: Vehicle-to-Pedestrian casualties in Germany in year 2011**

Pedestrians	Total		Killed		Seriously injured		Slightly injured	
Urban roads	34,708	94%	434	69%	8,179	92%	26,095	95%
Out of town	2,313	6%	191	31%	675	8%	1,447	5%
Total	37,021	100%	625	100%	8,854	100%	27,452	100%

According to the official statistics, traffic accidents involving pedestrians (two parties) mostly occur with passenger cars. In 2011 there were 22,160 accidents in this case (73%) of a total of 30,547 traffic accidents involving pedestrians. The second most frequent pedestrian collision partners are bicycles (13%) [2].

The national accident statistics in Germany (free annual reports) do not reveal the exact situation of conflict (detailed accident type code) that lead to accidents between cars and pedestrians. However, a number of states of Germany (states distributed over the country) document those accidents with the three-digit type of accident. For the purpose of this accident research, these data were pooled from six states and analyzed. This data set covers 42% of all observed fatal crashes involving passenger cars and pedestrians (max. two parties) in Germany and is assumed to be representative. In order to obtain the largest possible data set and to even out annual fluctuations, a period of three consecutive years (2008 to 2010) was chosen ( $n_{\text{fatal}} = 399$ ;  $n_{\text{serious}} = 6,875$ ;  $n_{\text{slight}} = 21,751$ ).

The analysis performed focused on seriously injured and killed pedestrians (impacted by passenger cars) and showed that the major conflicts (crash configurations) with regard to seriously injured people and fatalities can be reduced to the following accident scenarios:

- Pedestrian crossing from near- or off-side without obstruction,
- Pedestrian crossing from near-side behind an obstruction and
- Pedestrian goes along the road without obstruction.

In addition to these scenarios, further scenarios were identified in addition to the preliminary accident scenarios:

- Darkness in scenarios 3 and 4
- Scenario 8 ‘Crossing before or after junctions’
- Scenario 9 ‘Reversing’

The accident scenario 8 (pedestrian crossing directly before or after an intersection; see Figure 2) was separately handled within the German analysis. It is believed that this accident scenario 8 shows a special traffic situation with generally a high number of objects around (vehicles, traffic requirements), crowds of people, multiple lanes and maybe constitutes for a most difficult situation for pre-crash safety systems due to the overall environmental complexity.



**Figure 2: Accident Scenario S8 “Crossing before or after junctions” (identified apart in German accident data)**

It has to be noted that accidents allocated to accident scenario 8 were assigned to accident scenarios 1 and 2, for comparison with British data and for later extrapolation since the relevance of this environmental complexity could not be clarified sufficiently yet.

While for adults and elderly people the proportions of the most frequent accident scenarios were similar, the scenario ‘crossing behind an obstruction’ was over-represented for children. Children were defined up to the age of 11 years inclusively, differently from other commonly used definitions. This selection was made under the assumption that causes of accidents change for older children. Thus, children under the age of 11 years are more frequently obscured by parked cars, while the growth in size changes significantly later. It appears that children frequently cross from the nearside or offside of the road (mostly straight road layout) in daylight (accident scenarios 1 and 2) and thereby be involved in serious accidents (31% of seriously injured and 50% of killed children, see [5]). Further, children cross the road from the nearside, so are particularly common obstacles (e.g. parked vehicles) in the field of view of the car driver (accident scenario 5; 22% of seriously injured and 14% of killed children, see [5]).

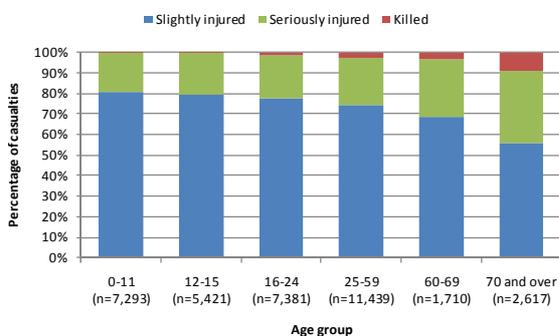
Further, it is evident that car-to-pedestrian crashes during ‘dark’ light conditions led to more serious injuries or even the death of pedestrians compared to ‘day’ light conditions.

## Results Great Britain

The STATS19 analyses were used to identify common accident scenarios of car-to-pedestrian crashes (here ‘car’ is referred to passenger cars as well as taxis) and appropriate weighting factors for them. The analysis involved identifying all pedestrian casualties in STATS19; identifying the target population, i.e. pedestrian casualties impacted by the front of a car or taxi and the examining of characteristics of the target population; in particular to determine the proportion injured in each of the preliminary accident scenarios defined.

In total, between 2008 and 2010, 12% of casualties in Great Britain were recorded as pedestrians. Pedestrians accounted for the second largest casualty group after car occupant casualties (64%). Pedestrian casualties recorded as being hit by a car or taxi, where the first point of contact on the associated vehicle was the front, were selected as being members of the target population (46% of the pedestrian casualties). A secondary filter was then applied to remove casualties hit by stationary or reversing vehicles, as these situations were deemed to be inappropriate for this analysis. The final target population consisted of 36,678 pedestrian casualties ( $n_{\text{fatal}} = 803$ ;  $n_{\text{serious}} = 8,169$ ;  $n_{\text{slight}} = 27,706$ ). Pedestrian casualties impacted by the front of a car (or taxi) were defined as members of the target population for this work.

Figure 3 displays the proportion of casualties in each injury severity by age group. It should be noted that the age groups defined are not equal in size; 32% of pedestrian casualties were aged 25-59 years, 21% were aged 16-24, 15% were aged 12-15 and 20% were under 11. The combined older age groups (60-69 and 70 and over) only accounted for 12% of pedestrian casualties. Age was unrecorded for 817 casualties and as a result, these have been excluded from this analysis.



**Figure 3: Proportion of pedestrian casualties in each severity by age group, 2008 – 2010, GB**

A higher proportion of pedestrian casualties in the older age groups were killed or seriously injured when compared to those in the younger categories. Pedestrians aged 70 and over recorded the highest

percentage of casualties killed or seriously injured with 44% falling into these two categories.

Pedestrian casualties are more common on urban than rural roads; 88% of casualties in the target population were recorded in urban areas. However, pedestrians were more severely injured on rural roads than urban; 33% were killed or seriously injured compared to just 23% on urban roads. Pedestrians are rarely injured on motorways (there were only 68 in the target population). However, 74% of these were killed or seriously injured.

Summarised:

- 24% of casualties in the target populations were killed or seriously injured (larger in the older age groups);
- 88% of casualties were injured in urban areas;
- The most common junction characteristics included ‘not at within 20 m of junction’ (43%), ‘T or staggered junction’ (36%) & ‘crossroads’ (10%);
- The most common vehicle manoeuvre was ‘going ahead other’ (68%);
- The most common pedestrian movements were ‘crossing from nearside’ (31%), ‘in carriageway standing or playing’ (19%), ‘crossing from offside’ (16%);
- A substantial proportion of casualties were impacted when ‘crossing on pedestrian crossing facility’ (30%);
- A significant proportion of accidents had the contributory factor ‘impaired by alcohol’ assigned to the pedestrian (10-20% depending on injury severity).

It should be noted that obscuration in STATS19 only includes pedestrians masked by a parked or stationary vehicle. Pedestrians masked by other objects such as street furniture are classified as no obstruction.

## Pedestrian speed

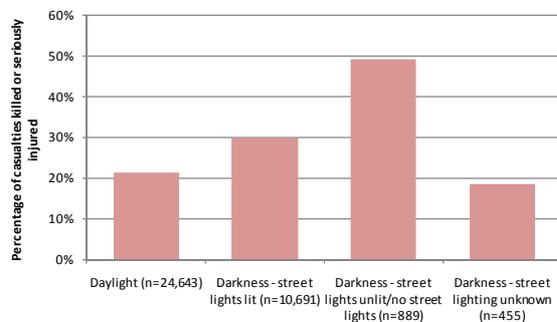
Estimating the speed of the pedestrian is more difficult compared to reconstruct a vehicle’s speed and can usually not be derived from evidence at the scene of the collision. However, there are various other sources of pedestrian speed data for use in accident reconstruction. These often present detailed walking and running speed data broken down by age and gender. Within the AsPeCSS project reasonable approximations for pedestrian walking and running speeds were derived from a literature review[5] and are shown in Table 4. They may also be suitable for use in pedestrian test scenarios. The same speed is proposed for adults and children (as well as males and females) for simplicity.

**Table 4: Pedestrian speeds as used in AsPeCSS**

Speed	Adults and children (m/s)	Elderly (m/s)
Walking	1.4 (≈ 5 km/h)	1.2 (≈ 4 km/h)
Running	2.8 (≈ 10 km/h)	2.0 (≈ 7 km/h)

### Accidents during ‘dark’ light conditions

Figure 4 shows the proportion of killed or seriously injured (KSI) pedestrian casualties by light condition in the STATS19 database from years 2008-2010. In the target population, 24,643 (67%) KSI pedestrian casualties were injured in daylight and 29% in darkness with street lights. However, a higher proportion of KSI pedestrian casualties were injured at night on roads where there were no street lights or they were unlit than any other light condition.



**Figure 4: Proportion of KSI pedestrian casualties by light condition, 2008 – 2010, GB**

From this and the German accident analysis ‘dark’ light conditions were identified as a central contributing factor to severe injury outcomes of car-to-pedestrian crashes, especially with regard to pedestrian fatalities – 83% of all pedestrian fatalities in the British and German datasets resulting from accidents between a passenger car and a pedestrian were assigned to the AsPeCSS final accident scenarios, and on average 58% of these occurred during ‘dark’ light conditions (see Table 8).

The available national accident data from Great Britain and Germany were used to generate an overview of the importance of the ‘dark’ light condition (including the average of both countries) and are shown for killed and seriously injured (KSI) pedestrian casualties in Table 7 and for fatally injured pedestrian casualties in Table 8. For each country and for the average values the three most frequent accident scenarios are marked in bold. With regard to KSI, on average 25% of car-to-pedestrian crashes were assigned to scenario 1, 20% to scenario 2 and 15% to scenario 7, whereby ‘dark’ light conditions prevailed in accident scenario 2. With regard to fatalities, on average 30% of car-to-pedestrian crashes were assigned to scenario 2, 23%

to scenario 1 and 19% to scenario 7. The ‘dark’ light condition stands out in terms of pedestrian fatalities as can be seen in the percentages of Table 8. The rate of accidents in ‘dark’ light conditions accounts for 65% to scenario 1, for 77% to scenario 2 and for 74% to scenario 7.

The analysis above shows that often collisions with a car in dark light conditions end up with serious injuries or death of the pedestrian. Figure 5 shows randomly chosen accident scenes at night from GIDAS. Since a majority of accidents occur in urban areas, there is almost never complete darkness, but always a diffuse illumination by streetlights, traffic lights, street furniture or similar reflections on the wet roadway and / or bright lights from the headlamps. These driver demanding light conditions often occur combined with obstructions and thus lead to a more complex situation.



**Figure 5: GIDAS examples of car-to-pedestrian collisions on German roads at night with glare, rain, reflections and obstructions**

### ASPECSS ACCIDENT SCENARIOS

#### Overview

To take results of previous projects into account, available literature was reviewed and was summarised into preliminary accident scenarios for AsPeCSS (see above). Though the preliminary accident scenarios were largely confirmed by current analyses of German and British data, the accident scenario 3B ‘Crossing at junction, near- or off-side, vehicle turning across traffic, dark’ and accident scenario 4B ‘Crossing at junction, near- or

off-side, vehicle not turning across traffic, dark' were added to the final list of Accident Scenarios for AsPeCSS, see Table 5. Accident scenario categories 'Reversing' and 'Parking' were excluded due to their small relevance regarding the forward-looking systems addressed within AsPeCSS.

**Table 5: AsPeCSS Accident Scenarios**

Drawing	ID	Accident Scenario Description
	1 A/B	Crossing straight road, nearside, no obstruction, day / dark
	2 A/B	Crossing straight road, offside, no obstruction, day / dark
	3 A/B	Crossing at junction, near- or offside, vehicle turning across traffic, day / dark
	4 A/B	Crossing at junction, near- or offside, vehicle not turning across traffic, day / dark
	5 A/B	Crossing straight road, nearside, obstruction, day / dark
	6 A/B	Crossing straight road, offside, obstruction, day / dark
	7 A/B	Along straight road, no obstruction, day / dark

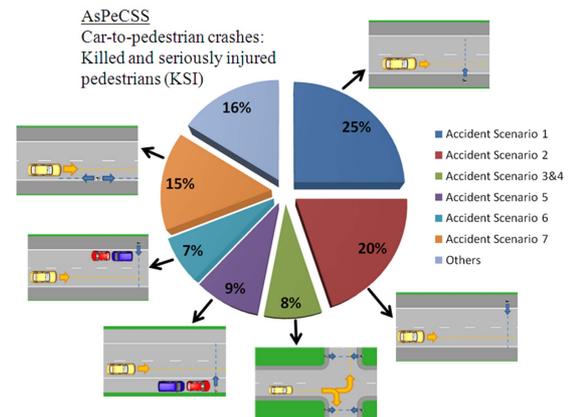
**Relevance**

The seven preliminary accident scenarios were confirmed to be relevant for Great Britain and Germany and weighting factors obtained. In view of these factors accident scenarios 3 and 4 were joined together. The final AsPeCSS accident scenarios with weighting factors for all pedestrian casualties are given for GB and Germany in Table 6. Highest weights were assigned to scenarios 1 (23%) and 2 (16%), followed by scenario 7 (13%).

**Table 6: AsPeCSS Accident Scenarios of car-to-pedestrian crashes in day and dark light conditions (averaged national accident data from GB and Germany of years 2008-2010 for all pedestrian casualties)**

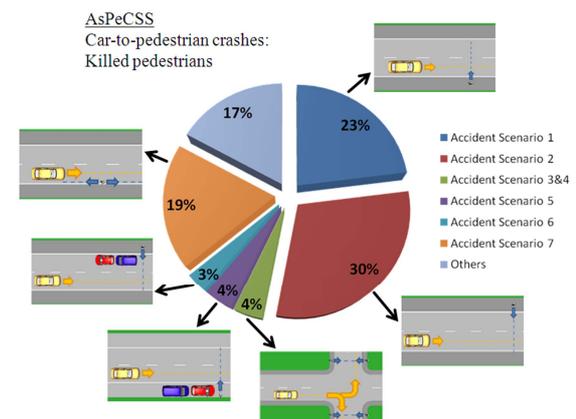
Accident Scenarios	Description	Light condition	All pedestrian casualties			
			GB	Germany	Average	
	Crossing a straight road from near-side; No obstruction	All (day/dark)	26 (18/8)	19 (13/6)	23 (16/7)	
	Crossing a straight road from off-side; No obstruction	All (day/dark)	13 (8/5)	18 (10/8)	16 (9/7)	
	Crossing at a junction from the near- or off-side with vehicle turning or not across traffic	All (day/dark)	6 (6/0)	7 (3/4)	6 (4/2)	
	Crossing a straight road from near-side; With obstruction	All (day/dark)	5 (4/1)	7 (6/1)	4 (3/1)	
	Crossing a straight road from off-side; With obstruction	All (day/dark)	7 (5/2)	5 (4/1)	8 (6/2)	
	Along the carriageway on a straight road; No obstruction	All (day/dark)	22 (15/7)	7 (4/3)	13 (9/4)	
TOTAL			All (day/dark)	79 (56/23)	63 (40/23)	70 (47/23)

Figure 6 shows the weights of the final AsPeCSS accident scenarios (car-to-pedestrian crashes) focusing on killed and seriously injured (KSI) pedestrians using national data from GB and Germany. Highest weights were assigned to scenario 1 (25%; crossing straight road, nearside, no obstruction), followed by scenario 2 (20%; crossing straight road, offside, no obstruction), others (16%) and scenario 7 (15%, along straight road, no obstruction).



**Figure 6: AsPeCSS Accident Scenarios – Overview of killed and seriously injured (KSI) pedestrians in crashes with cars**

Figure 7 shows the weights of the accident scenarios (car-to-pedestrian crashes) limited to killed pedestrians using national data from GB and Germany. Highest weights were assigned to scenario 2 (30%; crossing straight road, offside, no obstruction), followed by scenario 1 (23%; crossing straight road, nearside, no obstruction), scenario 7 (19%, along straight road, no obstruction) and others (17%).



**Figure 7: AsPeCSS Accident Scenarios – Overview of killed pedestrians in crashes with cars**

In summary, accident scenarios 1, 2 and 7 were found as the three highest weighted scenarios for car-to-pedestrian crash configurations (sum of

weights concerning KSI is 60% and concerning fatalities is 72%) that may potentially be addressed by forward-looking integrated pedestrian safety systems. However, accident scenarios 3&4, 5 and 6 (KSI: 24%, Fatalities: 11%) also have a significant weighting as regards future active pedestrian protection systems.

## CONCLUSIONS OF ACCIDENT DATA ANALYSIS

There were missing data in all of accident data sources (e.g. total numbers of casualties or vehicle speeds). Thus, a combination of sources and information was used and analysed under consideration of the particularities existing in the countries. However, some general observations could be made.

Similarities within all accident data sources regarding car-to-pedestrian crashes:

- Higher proportion of car-to-pedestrian crashes in urban areas, but higher injury severity on rural roads
- Elderly recorded the highest percentage of casualties killed or seriously injured
- Higher proportion of pedestrian casualties killed or seriously injured when hit by a car in dark light conditions
- Winter months November, December and January show higher number of car-to-pedestrian crashes compared to other months

Differences / deviations within all accident data sources regarding car-to-pedestrian crashes:

- Proportion of pedestrian casualties in crashes with a car (GB: 46% (car front crashes only), GER: 60%) of all crashes with pedestrians.
- Recognition of obstructions (i.e. in the GB 'obscuration' only includes pedestrians masked by a parked or stationary vehicle but other contributors are possible such as clutter close to pedestrian crossings).

For the comparison of KSI (killed and seriously injured) cases (MAIS2+) 84% of GB data and 83% of German data were included. With regard to fatalities 78% of GB data and 87% of German data were included. Remaining percentages include other car-to-pedestrian crash configurations, such as while parking or reversing.

Furthermore, some intersection issues identified in the German data analysis were declared as accident scenario 8 (crossing before or after a junction). In the British data analysis, this accident scenario 8 is included in accident scenarios 1 and 2 and could be seen as subgroups of these. Because it was not sure what the sensitivity of pre-crash safety systems is to

the environmental complexity identified in this accident scenario, it was decided, for the time being, that this accident scenario should not be included in the AsPeCSS scenarios and that the related cases from the German data analysis should be assigned to accident scenarios 1 and 2.

Comparison of distribution of casualties by KSI (see Table 7) shows that accident scenarios 1, 2 and 7 are most frequent for both GB and Germany. Significant differences between countries can be seen in accident scenarios 2 and 7 as well as a significant proportion of KSI in dark lighting conditions.

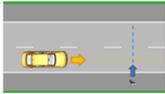
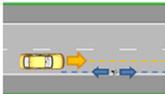
Comparison of distribution of casualties by fatality (see Table 8) shows that accident scenarios 1, 2 and 7 are again the most frequent for both GB and Germany. Significant differences can be seen in accident scenarios 2 and 7 as well as a high share of fatalities during darkness.

Comparison of distribution of all casualties (see Table 6) shows that accident scenarios 1 and 2 are the most frequent for both GB and Germany followed by accident scenario 7 for GB and accident scenarios 3, 4 and 7 (same value each) for Germany, respectively. Significant differences can be seen in accident scenarios 1 and 7 as well as a high share of fatalities during darkness. It has to be noted that 27% of all pedestrian casualties within the German dataset could not be assigned to one of the seven AsPeCSS' accident scenarios.

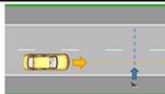
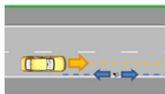
Compared in total, German data show major issues when a pedestrian crosses a road from off-side during dark light conditions without contributing view obstructions (accident scenario 2). In contrast, GB data show major issues when a pedestrian goes along the carriageway without contributing view obstructions (accident scenario 7).

The seven preliminary accident scenarios were confirmed to be relevant for Great Britain and Germany and weighting factors were obtained. In view of these factors accident scenarios 3 and 4 were joined together. The final AsPeCSS accident scenarios with weighting factors were calculated for all pedestrian casualties for GB and Germany. Hereby, highest weights were assigned to scenarios 1 (23%) and 2 (16%), followed by scenario 7 (13%).

**Table 7: AsPeCSS' Accident Scenarios of car-to-pedestrian crashes in day and dark light conditions (national accident data from GB and Germany of years 2008-2010 regarding killed and seriously injured (KSI) pedestrians)**

Accident Scenarios	ID	Description	Light condition	Killed and Seriously Injured (KSI)		
				GB	Germany	Average
	1	Crossing a straight road from near-side; No obstruction	All (day/dark)	<b>27</b> (16/11)	<b>24</b> (14/10)	<b>25</b> (15/10)
	2	Crossing a straight road from off-side; No obstruction	All (day/dark)	<b>16</b> (8/8)	<b>24</b> (11/13)	<b>20</b> (8/12)
	3, 4	Crossing at a junction from the near- or off-side with vehicle turning or not across traffic	All (day/dark)	4 (4/0)	<b>12</b> (6/6)	8 (5/3)
	5	Crossing a straight road from near-side; With obstruction	All (day/dark)	6 (4/2)	11 (9/2)	9 (7/2)
	6	Crossing a straight road from off-side; With obstruction	All (day/dark)	7 (5/2)	7 (5/2)	7 (5/2)
	7	Along the carriageway on a straight road; No obstruction	All (day/dark)	<b>24</b> (14/10)	5 (2/3)	<b>15</b> (8/7)
TOTAL			All (day/dark)	84 (51/33)	83 (47/36)	84 (48/36)

**Table 8: AsPeCSS' Accident Scenarios of car-to-pedestrian crashes in day and dark light conditions (national accident data from GB and Germany of years 2008-2010 regarding killed pedestrians)**

Accident Scenarios	ID	Description	Light condition	GB	Fatalities Germany	Average
	1	Crossing a straight road from near-side; No obstruction	All (day/dark)	<b>23</b> (8/15)	<b>23</b> (8/15)	<b>23</b> (8/15)
	2	Crossing a straight road from off-side; No obstruction	All (day/dark)	<b>20</b> (7/13)	<b>40</b> (8/32)	<b>30</b> (7/23)
	3, 4	Crossing at a junction from the near- or off-side with vehicle turning or not across traffic	All (day/dark)	2 (2/0)	5 (3/2)	4 (3/1)
	5	Crossing a straight road from near-side; With obstruction	All (day/dark)	2 (1/1)	6 (3/3)	4 (1/3)
	6	Crossing a straight road from off-side; With obstruction	All (day/dark)	4 (2/2)	3 (1/2)	3 (1/2)
	7	Along the carriageway on a straight road; No obstruction	All (day/dark)	<b>27</b> (9/18)	<b>11</b> (2/9)	<b>19</b> (5/14)
TOTAL			All (day/dark)	78 (29/49)	88 (25/63)	83 (25/58)

## Driving and Collision Speeds

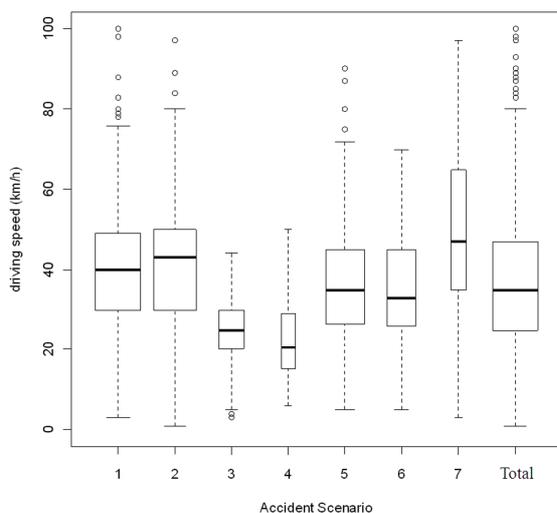
National accident databases usually do not provide sufficient data in terms of driving and/or collision speed of vehicles. Though in STATS19 (GB) information about the speed zone is given for each accident, this is of limited use in determining the actual driving speed of the vehicle. Thus, the German in-depth accident study GIDAS (years 2000-2011) was used to determine vehicle speed data in car-to-pedestrian crashes.

Note: the driving speed or initial velocity is defined as the speed in km/h before a critical situation was recognised. The collision speed is the speed of the vehicle in km/h at the time of collision. The speed change (delta V) is the difference between a car's driving and collision speed in the relevant impact.

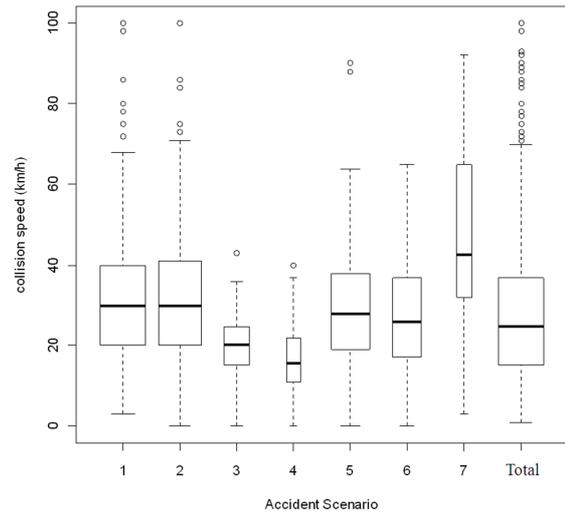
The initial GIDAS dataset used contained 2,113 pedestrian casualties. To ensure a comparable dataset, crashes with known vehicle speeds (e.g. by reconstruction) were selected. Thus, the GIDAS analysis used the following data query:

- Car-to-pedestrian crash
- All injury severities (pedestrians)
- Known driving speeds (> 0 km/h)
- Known collision speeds

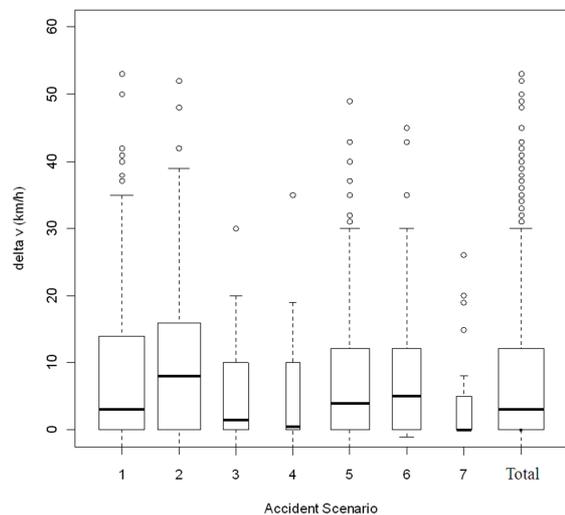
This resulted in a dataset containing 1,432 pedestrian casualties of all injury severities. Figure 8 shows boxplots of the passenger car driving speeds for each accident scenario and for all crashes. The median driving speeds differ widely from 47 km/h (scenario 7) to 20 km/h (scenario 4). Figure 9 shows boxplots of the passenger car collision speeds for each accident scenario and for all crashes. The median collision speeds differ again widely from 42 km/h (scenario 7) to 16 km/h (scenario 4).



**Figure 8: Boxplots of known driving speeds (>0 km/h) for each accident scenario and all accidents**



**Figure 9: Boxplots of known collision speeds for each accident scenario and all accidents**



**Figure 10: Boxplots of known speed change (delta V) for each accident scenario and all accidents**

Figure 10 shows the speed changes that occurred in each individual crash per accident scenario and for all accidents. All medians of these delta V values are below 10 km/h and around 4-5 km/h.

The calculated speed changes (delta V) for each accident scenario could be taken as a general basis for the estimation of braking behaviour within each accident scenario. Scenarios 3 and 4 (vehicle turning) showed together with scenario 7 smallest differences (compared to other scenarios) between driving and impact speeds which implies that there was no braking by the driver in most cases. However, this was strongly linked to the overall lower speeds. Further, it is interesting to note that the speed changes in scenario 2 (crossing pedestrian from offside without obstruction) were slightly higher than in scenario 1 (crossing pedestrian from nearside without obstruction). This might indicate the earlier recognition of the pedestrian crossing

from offside. The very low speed changes in scenario 7 (walking along) indicate that the driver did hardly ever react to the present of the pedestrian. This was maybe due to late recognition, an incorrect estimation of the pedestrians' behaviour or the absence of crash avoidance actions by the pedestrian.

In [5] another analysis was performed by dividing all pedestrian injuries into groups 'all injury severities' (MAIS > 0) and 'high injury severity' (MAIS 2-6). Conclusions drawn from that analysis were:

- On average the driving and impact speeds were higher (~10 km/h) when focussing on high injury severity pedestrian casualties.
- Highest driving and impact speeds were seen for the 95<sup>th</sup> percentile in scenario 7 (pedestrian walking along the road), followed by scenarios 1 and 2 (both crossing pedestrian without obstruction), followed by scenarios 5 and 6 (both crossing pedestrian with obstruction) and scenarios 3 and 4 (vehicle turning).



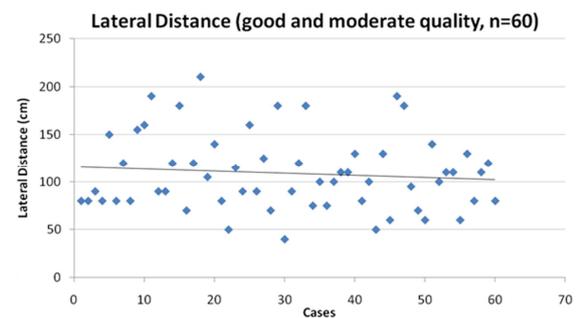
**Figure 11: Case examples ('good quality') for the lateral distance analysis using GIDAS (white arrows indicate childs' moving direction)**

## Lateral distance

Within AsPeCSS an accident data (GIDAS) study was performed to quantify the distances (here referred as 'lateral distances') between a subject vehicle and an obstruction in car-to-pedestrian crashes. Here, the accident scenario 'Child runs onto the road from near-side from behind an obstruction' was selected (see examples in Figure 11), since there is a lack of information with regard to the lateral distance.

The case-by-case analysis focused on photos, evidences for distances, information about vehicle and tram track widths, accident scene drawings true to scale etc. Finally, the crashes were categorised to three quality levels (poor, moderate and good) regarding the ability to provide information about the lateral distance. Hereby, 'good quality' is referred to an accident record that enables a realistic understanding of the distance between the car and the obstruction. The analysis classified 75 relevant crashes into the three quality levels ( $n_{\text{good}} = 26$ ,  $n_{\text{moderate}} = 34$ ,  $n_{\text{poor}} = 10$ ,  $n_{\text{NA}} = 5$ ); whereby cases assigned to the moderate and good quality were used for the definition of the lateral distances. Figure 12 shows the results of the lateral distance analysis, whereby the median was 100 cm.

In conclusion, 100 cm are recommended as lateral distance between the exterior of the subject vehicle (excluding side mirrors) and the object causing obstruction (e.g. parked car or bus) [5].



**Figure 12: Results of GIDAS analysis of the lateral distance between the exterior of the subject vehicle and the 'obstruction causing object' in accident scenario 'Child runs onto the road from near-side from behind an obstruction'**

## TEST SCENARIOS

### Methodology for definition of test scenarios

Test scenarios should represent the accident situation and thus real conditions. But rebuilding those scenarios in the laboratory or on a test track is very complex, if all characteristics would be reproduced in detail. It still has to be investigated which set of characteristics may be omitted as long as these do not influence the performance of any AEB (Automatic Emergency Braking) system.

The methodology to generate test scenarios used within ASPECSS was composed of two steps:

Firstly, a simplified model for the accident kinematics was generated. This model was based on the fact that if there was a pedestrian accident, then the pedestrian and vehicle must have shared one point in space for one specific time, i.e. the impact. Then assuming speeds for the pedestrian and the vehicle, assuming an angle between their paths and use these assumptions to derive their motion in the pre-crash phase. This simplified model is completely independent from current or future performance of AEB systems.

Next, a simplified model for the performance of AEB systems was derived based on the sequence detection of pedestrian – decision for braking – increase of brake pressure – full braking. Assume a decision logic for the brake system based on pedestrian dynamics and current product liability laws. Assume characteristics of current and future brake systems and calculate the performance. With the knowledge defined in these two steps, relevant parameters can be isolated. This helps defining a very limited set of test scenarios that still represent a large number of accidents.

### **Selection Criteria**

Test scenarios are an abstraction of key characteristics of accident scenarios that can be reproduced in a test environment. The choice of test scenarios was driven by the following factors:

- Should reflect real-world conditions as accurately as possible.
- Should include a variety of different accident scenarios, not necessarily accidents with highest frequency only (also in order to avoid constraining system design).
- Consideration of current system capabilities (different technologies) and testing feasibilities (i.e. R&R, lighting condition)
- Consideration of driver / sensor situation perception

### **Parameters for AEB-Pedestrian functionality**

For automatic emergency braking, the pedestrian needs to be detected as a relevant target, and after that the brake force needs to be increased. This short functional description already contains the most relevant parameters which can be used to define test scenarios: The time needed for detection of the pedestrian, and the time needed to increase the brake force from no to full braking. To avoid false activations, in general AEB functions will try to brake as late as possible. This reduces the relevant pre-crash time to the time needed to come to a full stop (depends on the speed but in general is < 1 s) and the detection time before that (< 1 s).

This means that all scenarios where the pedestrian is visible around 2 s before impact will very likely show the same performance – there is no need to have test scenarios with larger initial Time-To-Collision (TTC) values.

On the other hand, there will be a significant drop in AEB performance when the pedestrian is visible later than around 2 s before the impact.

This threshold of e.g. 2 s corresponds to a walking distance of around 3 m for the walking adult (5 km/h), and 1.7 m for the walking elderly (3 km/h). System-wise, there are two different types of scenarios: those where the pedestrian was visible 3 m laterally from the impact point (1.7 m for the walking elderly), and those where the pedestrian was visible laterally closer to the impact point.

In other words: all accident scenarios with the pedestrian and vehicle travelling at constant speeds and constant paths can be classified either as obstructed scenarios or as unobstructed scenarios. And from a system symmetrical performance point of view, an off-side obstructed scenario is same as a near-side scenario. The term off-side implies that the pedestrian having an accident, comes from the far side of the road from behind the other lane going towards its impact point, which will be farther than the 3 m from the impact point.

Besides these most contributing parameters, other relevant parameters are environmental conditions as well as the trajectory of the vehicle. For instance the environmental conditions, in particular the lighting, are expected to affect the performance of most AEB-Pedestrian (AEB-P) systems significantly. And, there are a few accident scenarios where the vehicle does not travel on a constant course but performs a turn in the pre-crash phase. The AEB-P performance in these situations may or may not be comparable.

### **Base and Enhanced Test Scenarios**

The test scenarios defined by AsPeCSS follow these considerations: Test Scenario (TS) 1 features a running child from behind an obstruction at 1 m lateral distance to the vehicle path and is an ‘obstruction’ type scenario, while TS2 and TS3 are ‘non-obstruction’ type scenarios during daytime. TS2 and TS3 will also be tested during night conditions once available. The classification of ‘child’, ‘adult’ and ‘elderly’ to the test scenarios was made based on the related assignment of personal data to the accident scenarios (see [5]) and mirrors the size and walking speed (see Table 4) of pedestrians.

Turning maneuvers will be covered by a specific test scenario as well as crossing before or after complex intersections and scenarios where the pedestrian is walking along a road on the near-side in the vehicle driving direction. This latter scenario

is technically an ‘unobstructed’-type scenario with a lateral pedestrian speed of zero, but the longitudinal speed of the pedestrian is relevant for detectability by some kinds of sensors, even if it is low.

As a first step and since testing tools and set-ups are not yet available to address crossing situations and conditions under darkness, Base Test Scenarios have been developed to be testable within the next two years. In addition, Enhanced Test Scenarios will be developed in a later phase.

Further, the AsPeCSS project aims to at least investigate the reaction of AEB-P systems in cases where e.g. the pedestrian stops its movement and thus avoids the collision (‘tests with stopping pedestrian avoiding the crash’). Test scenarios for this will also be developed in a further stage of the project. See Table 9 for a full list of the scenarios.

**Table 9: AsPeCSS Test Scenarios**

ID	Test Scenario Description
Base Test Scenarios	
TS1	Child crosses from near-side behind an obstruction
TS2a	Elderly crosses from off-side (unobstructed)
TS3a	Adult crosses from off-side (unobstructed)
Enhanced Test Scenarios (to be decided)	
TS2b	Elderly crosses from off-side in twilight
TS3b	Adult crosses from off-side in darkness
TSx	Turning manoeuvre
TSx	Pedestrian goes along the road (maybe with bend)
TSx	Crossing before or after a complex intersection
Tests with stopping pedestrian avoiding the crash	

### Mapping Accident Scenarios to Test Scenarios

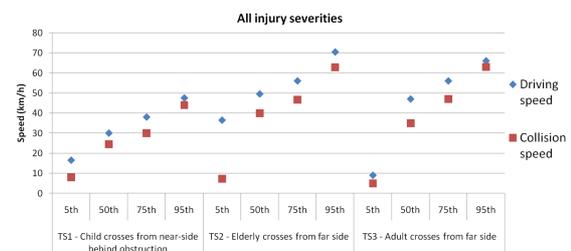
Major differences between the test scenarios are the walking speed of the pedestrian and the obstruction status (with or without). Based on these factors, one test scenario can be associated with a number of accident scenarios. The mapping relationship between accident and base test scenarios is shown in Table 10 where the averaged weight for pedestrian fatalities of crashes with cars is added for daylight and dark light conditions. Basically, TS1 is assumed to address accident scenario 5 and thus a system highly demanding scenario. Further, TS2 and TS3 are assumed to address accident scenarios 1, 2, 3&4 and 6. Question marks are included in Table 10 in fields where it is believed that pedestrian pre-crash sensing systems may cover potentially (ranging from partial to full) the accident scenarios (e.g. in dark light conditions depending on the kind of sensor technology and/or system evaluation characteristics). This mapping of scenarios is currently ongoing work within AsPeCSS.

**Table 10: Mapping from Accident Scenarios to Base Test Scenarios including light conditions (‘?’ indicates partial to full addressability)**

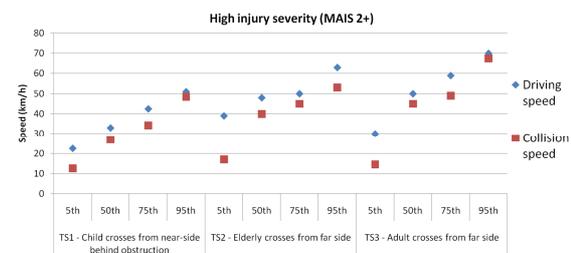
ID	Accident Scenario Description	Fatalities (%)	Daylight	Twilight	Darkness
1 A/B	Crossing a straight road from near-side; No obstruction	23 (8/15)	☀	☾?	☀? ☾?
2 A/B	Crossing a straight road from off-side; No obstruction	30 (7/23)	☀	☾?	☀? ☾?
3 A/B	Crossing at a junction from the near- or off-side with vehicle turning or not across traffic	4 (3/1)	☀	☾?	☀? ☾?
4 A/B	Crossing a straight road from near-side; With obstruction	4 (1/3)	☀	☾?	
5 A/B	Crossing a straight road from off-side; With obstruction	3 (1/2)	☀	☾?	☀? ☾?
6 A/B	Along the carriageway on a straight road; No obstruction	19 (5/14)			

### Test Scenario Parameters

Driving and collision speeds have been analysed using the in-depth accident database GIDAS to support the development of test scenarios with realistic speed ranges. Figure 13 and Figure 14 show speeds of passenger cars involved in crashes with pedestrians according to the specifications for the Base Test Scenarios defined, subject to all injury severities and high injury severity (MAIS 2+), respectively. In all datasets used (designated to the three Base Test Scenarios) higher speeds were present in case of MAIS 2+ injured pedestrians. Speeds are generally lower for TS1 than for TS2 and TS3 which is directly connected with the location of usual occurrence - urban roads. Because of these data and current testing feasibilities (mainly due to the pedestrian dummy robustness) the upper testing speed limit was set to 60 km/h. Further, it was recommended to set the lower testing speed limit not below 10 km/h.



**Figure 13: Vehicle speeds by analysis of GIDAS data (all pedestrian injury severities, not weighted, years 2000-2011)**



**Figure 14: Vehicle speeds by analysis of GIDAS data (high pedestrian injury severity by MAIS 2+, not weighted, years 2000-2011)**

The AsPeCSS project also defines varying impact positions of the pedestrian on the vehicle front: 50% (= center impact) for TS2 and TS3 and 25% / 75% (on vehicle front, approx. 40 cm from the left and right vehicle side) for TS1. A detailed explanation of impact position and its effect on the expected system performance can be found in [5], and [8].

## WEIGHTING FACTORS FOR EUROPE

### Approach

Accident scenario weighting factors derived from national accident data from Germany and the GB were used to extrapolate to the EU-27 countries. In AsPeCSS, detailed data related to crashes with pedestrians was available from GB, Germany, partly from France and the Netherlands but not as a whole for the EU-27. Even the high-level compiled EU accident databases (i.e. CARE, IRTAD) offered little information. Thus, a statistical approach was needed to extrapolate the available data (and proportions) to Europe (EU-27).

The national accident data analysis within [5] and this paper focused on all car-to-pedestrian crashes in Germany and on frontal collision car-to-pedestrian crashes in GB (for the GB analysis it was assumed that lateral collisions with pedestrians should not be included in the target population because the forward looking pedestrian systems would not offer any benefit for them).

Due to several constraints, the post-stratification methods proposed initially could not be applied but the envisaged raking procedure and the Iterative Proportional Fitting (IPF) methods also proposed initially will be considered in a later stage of the AsPeCSS project.

Therefore, a simple approach which averaged the available accident data was chosen to calculate indicative weighting factors for Europe with regard to all seven accident scenarios.

Since the weighting factor analyses to date (see i.e. Table 7 and Table 8) are in relationship to a target population (car-to-pedestrian crashes) within all pedestrian casualties, a re-calculation of the weighting factors was needed (normalization) to provide an overview of the importance of the accident scenarios. That is, based on the analysis of the national accident data within [5] the new proportions of KSI, fatalities and all pedestrian casualties had to be calculated for Germany and GB. These proportions are shown in Table 11. While these percentages are similar for killed pedestrians in Germany (56%) and the GB (55%), the proportions for KSI differ between Germany (66%) and the GB (50%) as well as for all

pedestrian casualties between Germany (60%) and the GB (46%).

**Table 11: Proportion of seriously injured and/or killed pedestrians and all pedestrian casualties in crashes with a passenger car<sup>2</sup> against all seriously injured and/or killed pedestrians and pedestrian casualties in road traffic for Germany (average from years 2010 and 2011) and Great Britain (average from years 2008 – 2010)**

	Germany			Great Britain		
	KSI	Fatalities	All casualties	KSI	Fatalities	All casualties
Proportion of seriously injured and/or killed pedestrians in crashes with a passenger car against all seriously injured and/or killed pedestrians in road traffic	66%	56%	60%	50%	55%	46%

The proportions from Table 11 were now used to calculate the weighting factors for Germany and GB with regard to the AsPeCSS Accident Scenarios.

Finally, the calculated weighting factors from German and GB data were averaged to estimate initial weighting factors in this first phase of the AsPeCSS project. The results are listed in Table 12. No further marginal distributions (i.e. population or vehicle registration numbers) have been considered since their influences were not clarified. From this calculation the conclusion can be derived that the AsPeCSS Accident Scenarios cover nearly half of all killed pedestrians (46%) and nearly half of all seriously injured and killed (KSI) pedestrians (49%) as well as 37% of all pedestrian casualties in Europe.

**Table 12: Averaged weighting factors (%) of Accident Scenarios for killed and seriously injured (KSI), Fatalities and all pedestrian casualties of all crashes including pedestrians in GB and Germany**

Accident Scenario	KSI	Fatalities	All casualties
1	15%	13%	11%
2	12%	17%	9%
3+4	5%	2%	4%
5	5%	2%	3%
6	4%	2%	3%
7	8%	10%	7%

Finally, the assumption was made, that the weighting factors listed above represent valid proportions for all EU-27 countries. This strong assumption will be checked during further research work, whereby marginal distributions will be derived from EU accident data.

<sup>2</sup> GB data: Frontal passenger car / taxi / hired car collisions with pedestrians

## DISCUSSION AND LIMITATIONS

The analysis presented is limited to car-to-pedestrian crashes and hence, the impact of a potential future development of the test scenarios towards passenger car crashes with cyclists has not been considered yet. Due to the limitations in current testing procedures of active safety systems (e.g. 'dark' light conditions), base test scenarios were developed with the intention of adding enhanced test scenarios in future. These will take into account parameters such as turning manoeuvres, complex intersections and environmental conditions such as darkness, if found necessary, i.e. the performance of the system changes significantly with a change in these conditions.

## CONCLUSIONS

Within the European FP7 project AsPeCSS different European accident data sources have been used to investigate the causations and backgrounds of road traffic accidents with pedestrians. Analyses of high level national data and in-depth accident data from Germany and Great Britain was used to confirm and refine preliminary accident scenarios identified from other projects such as AEB and vFSS. General observations made included that a higher proportion of pedestrian casualties killed or seriously injured was found when hit by a car in 'dark' lighting conditions. Seven Accident Scenarios were identified (each divided into 'daylight' and 'dark' light conditions) which included the majority of the car-to-pedestrian crash configurations. Accident Scenarios were identified with weighting factors and associated test scenarios were developed to assess the performance of the pre-crash braking component of integrated pedestrian safety systems.

## ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of the European Commission, the UK Department for Transport (DfT) and the German Federal Ministry of Transport, Building and Urban Development for this work.

## REFERENCES

- [1] DaCoTa, European Road Safety Observatory, "Traffic Safety Basic Facts 2011 - Pedestrians," Project co-funded by the European Commission, 2012.
- [2] "Verkehrsunfälle 2011, Fachserie 8 Reihe 7," Statistisches Bundesamt, Wiesbaden, 2012.

- [3] EuroTest, "Pedestrian crossings survey in Europe, Final Report," 2008.
- [4] M. Mc Carthy e al., "The advanced protection of vulnerable road users (APVRU): Final report PR/SE/970/04," APVRU consortium, 2004.
- [5] M. Wisch, P. Seiniger, M. Edwards and C. Visvikis, "Scenarios and weighting factors for pre-crash assessment of integrated pedestrian safety systems (Deliverable 1.1)," AsPeCSS project, European Commission DG RTD Theme 7 Transport, 7th Framework Programme – SST.2011.RTD-1 GA No. 285106, 2013.
- [6] Autonomous Emergency Braking Test Group, "AEB test procedures," 2011. [Online]. Available: [http://www.thatcham.org/safety/pdfs/AEB\\_test\\_procedures\\_nov11.pdf](http://www.thatcham.org/safety/pdfs/AEB_test_procedures_nov11.pdf). [Accessed 30 July 2012].
- [7] F. Leimbach, "vFSS Group - Introduction and Status update," unpublished presentation, Euro NCAP PNCAP Meeting in Boxberg, 2011.
- [8] P. Seiniger, O. Bartels, C. Pastor and M. Wisch, "An Open Simulation Approach to Identify Chances and Limitations for Vulnerable Road User (VRU) Active Safety," *ESV Conference Paper 13-0021*, 27-30 May 2013, Seoul, South Korea.
- [9] M. Wisch, C. Pastor, P. Seiniger, O. Zander and B. Lorenz, "Reasons why passive pedestrian protection remains an issue for the future," in *Crash.Tech 2012*, München, 2012.
- [10] M. e. al, "The advanced protection of vulnerable road users (APVRU): Final report PR/SE/970/04," APVRU consortium, 2004.