Relevance on Injury Causation of Vehicle Parts in Car to Pedestrian Impacts in different Accident Configurations of the Traffic Scenario and Aspects of Accident Avoidance and Injury Prevention

Otte Dietmar,
Medical University Hannover
Accident Research Unit
Germany
Huefner Tobias,
Medical University Hannover
Department of Trauma Surgery
Germany
Paper Number 07-0176

ABSTRACT

This study is concerned with the analysis of pedestrian accidents and the corresponding analysis, which injuries are caused by what type of vehicle impact in different accident scenarios. The question is: to what extent can innovative driver assistance systems and measures in traffic environment help to avoid or completely prevent injuries of pedestrians. For this purpose, a total of n=1107 accidents documented in surveys in Hannover and Dresden involving passenger cars and pedestrians were examined and the injury situations shown. To this end, characteristic values such as driving and collision speed, injury severity MAIS and AIS of the individual injuries for different accident scenarios were regarded. For the identification of the relevant accident scenarios, classifications of the accident types were used and many of those represented in statistically representative accident material GIDAS (German in-Depth-Accident Study - 1) for the years 1995 to 2004 were filtered out. The study should be of assistance and support decision-making in the evaluation of future technical innovative measures for accident avoidance and thus injury reduction

INTRODUCTION AND TARGETS

Pedestrian safety has been significantly improved over the past 30 years. Where in 1975 in a country like the Federal Republic of Germany (STBA - 2) still n = 3973 fatalities and n = 60033 casualties among pedestrians were registered, the number of fatalities at n = 686 and casualties at n = 33803 in the year 2005 clearly seems like an improved situation. Nevertheless it cannot be overlooked that in today's Europe of 27 different countries, there are still far more than 40 000 pedestrians killed in traffic annually. This requires manifold efforts of scientific research, which can no longer be limited exclusively to passive security like injury reduction, but must also aim at measures of active security for the avoidance of accidents as well. Also, the requirements postulated by the European Union commission in the year 2000 for all member states to halve the number of deaths within the next 10 years, constitutes a difficult target to reach until 2010

The aim had been to increase the protection of pedestrians by implementing different phases. All new vehicles have had to pass phase 1 of EEVC pedestrian tests after October 1st, 2005 and all new registrations of existing models by 2012. As part of this Directive, a feasibility test was also conducted to evaluate to what extent manufacturers would be able to comply with the full test criteria defined by the EEVC (EU commission - 3). If strong arguments were put forward, proving that manufacturers would not be able to design vehicles to comply, then active safety systems would be evaluated to assess whether they would be able to make up the difference in estimated casualty reductions as a result of relaxing the tests recommended by EEVC. After negotiation with the industry, the EU proposed a regulation, which would incorporate all the present requirements of phase 1 and revised requirements for phase II based on a feasibility study. A first phase set of test requirements (phase I) was applied to all new types of vehicles as from October 1st, 2005 and to all new vehicles placed on the market after December 31st, 2012. A second phase of tests (phase II), based on the results of a comprehensive study into the feasibility of the original requirements, will apply to all new types of vehicles from September 1st, 2010 and to all new vehicles by 2015. Additionally, the active safety system, brake assist, will be required in all new vehicles from July 1st, 2008. The use of new systems, such as collision avoidance, will be recognised as alternatives. The two ways to encourage manufacturers to dedicate more resources towards protection issues are through consumer demand and setting high crash test standards that are relevant to the real world.

This study deals with the analysis of traffic accidents involving pedestrians and filtering the accident scenarios frequently occurring during such accidents. It is to be determined, whether collisions between passenger cars and pedestrians cause less severe injuries at pedestrian crosswalks than, for instance, in case of collisions on free stretches of the road or at junctions and/or intersections, and, for example, if other sources of injury at the vehicle are responsible for the injuries. Particular attention is paid to the severely injured pedestrians.

Such questions require a differentiating methodology for multi-phase analysis and comprehensively documented accident data, such as they are available due to collections at the sites of accidents, GIDAS. These records contain information concerning injuries and vehicle deformations besides data referring to places and types of accidents. Beyond that, there are detailed descriptions concerning the origins of accidents and the sequence of the accidents based on questioning the persons involved and documentation of the environment of the scene of the accident. These supply information in connection with the technical accident reconstruction regarding the speed the vehicles were traveling at and the collision speed on the basis of recorded skid marks and final positions of the vehicles.

CASE BASE AND METHODOLOGY

Since 1999 compilations have been conducted at the site of accidents, GIDAS (German in-Depth-Accident Studies, Otte - 4), at the medical university Hanover and the technical University of Dresden on behalf of the Federal Institution for roads, BAST, and the German Automotive industry FAT. The methodology is described by Brühning (1) and Otte (4). Based on a random sample, representative data processing can be done in connection with a statistic weighing of the data (Pfeiffer - 5). From a population of traffic accidents with personal injury documented by scientific teams in the years 1999 to 2005, accidents in which passenger cars and pedestrians were involved, were selected and for this sub-group the different accident scenarios were filtered. For this purpose, the classification according to accident types (FGSV - 6) and the recording of the environment of the accidents according to categories such as urban/rural, straight road/junction, with/without traffic lights, with/without line-of-sight obstructions was used. The analysis of the location and severity of the injuries was conducted based on the AIS- injury classification (American Association for Automotive Medicine - 7). The record of every accident contains a comprehensive reconstruction of the motion sequences of the vehicle and the pedestrian on the basis of a true-to-scale drawing based on an image created using 3-D-Laser technology showing the site of the accident and measured skid marks as well as the final positions of the vehicles (Otte -8).
1107 accidents with pedestrians constitute the basis of the analysis, of these 182 suffered an injury severity grade of MAIS higher than 2 (MAIS 3+). This corresponds to a portion of severely injured person of 16.4%.
For the identification of the relevant accident configurations, the accidents were now differentiated according to the origins of the accidents and the accident characteristics. For this purpose, the accident incidences for all pedestrians (table 1) and for severely injured /killed pedestrians (table 2) in a collision with a passenger car were illustrated. Tables 1 and 2 show that accidents on straight roads without safety features are the most frequent more than 50 % and accidents at intersections with traffic lights at around 10% and without traffic lights at 14.4% of all and at 19% of severely injured pedestrians are the second most frequent, in each case for passenger cars traveling straight ahead and pedestrians traversing the road. Taken together, these constitute already about 70% of all collisions resulting in severely injured pedestrians. Almost 90% of all accidents with pedestrians occur in principle at 3 different locations:

1 - straight roads without safety feature
2 - intersections without traffic lights with passenger car traveling straight ahead
3 - intersections with traffic lights with passenger car traveling straight ahead

Table 1.
Pedestrian accident situation and locations (n=1107)

		Movement of Pedestrian							
70 % of cases	total	contrary to car	same direction as car	from left no obstruct.	from left with obstruct.	from right no obstruct.	from right with obstruct.	enter or aboard	others, unknown
total	100.0%	9.0%	3.2%	16.8%	13.9%	24.4%	22.6%	3.7%	6.4%
Movement of Car									
intersection, no traffic light straight ahead	14.4%	0.5%	0.6%	2.6%	2.0%	3.7%	3.3%	0.7%	0.9%
intersection, no traffic light, turning left	2.5%	0.8%	0.2%	0.5%	0.0%	0.7%	0.2%	-	0.1%
intersection, no traffic light, turning right	1.5%	0.3%	0.1%	0.3%	0.1%	0.7%	0.0%	-	-
intersection, traffic light, straight ahead	10.8%	1.0%	0.1%	2.8%	1.0%	4.2%	1.3%	0.1%	0.3%
intersection, traffic light, turning left	3.8%	0.8%	0.2%	1.5%	0.1%	1.1%	-	-	0.1%
intersection, traffic light, turning right	1.5%	0.1%	-	0.4%	-	1.1%	-	-	-
curve	3.8%	1.2%	-	0.3%	0.6%	0.9%	0.8%	-	0.0%
straight line, no crosswalk	51.1%	3.8%	1.4%	6.4%	9.0%	9.1%	15.1%	2.9%	3.5%
straight line, crosswalk no traffic light	2.8%	-	-	1.0%	0.1%	1.4%	0.3%	-	-
straight line, crosswalk traffic light	0.4%	-	-	0.1%	0.1%	0.2%	-	-	
others	7.3%	0.5%	0.5%	0.9%	0.9%	1.4%	1.5%	0.1%	1.5%

Particularly significant are these groups: pedestrians approaching from the right with line-of-sight obstructions (15.1%), intersections with traffic lights and "pedestrians approaching from the right without line-of-sight obstructions" (4.2%) and intersections without traffic lights and "pedestrians approaching from the right without line-of-sight obstructions" (3.7%). If also considers the special lower level conflict situations (about 1 %), then all the marked boxes of the table offer the frequent accident situations involving pedestrians.

If only accidents resulting in severely and fatal injured pedestrians are regarded, a near analogy with all accidents can be noticed, nearly the same incidences apply (table 2).

Table 2.
Accident situation and locations of pedestrians MAIS 3+ (n=182)

		Movement of Pedestrian							
	total	contrary to car	same direction as car	from left no obstruct.	from left with obstruct.	from right no obstruct.	from right with obstruct.	enter or aboard	others, unknown
total	100.0%	12.2%	5.5%	21.8%	11.2%	21.3%	17.1%	2.1%	8.8%
Movement of Car									
intersection, no traffic light straight ahead	18.8%	1.3%	1.2%	4.9%	0.6%	6.5%	4.1%	-	0.2%
intersection, no traffic light, turning left	1.3%	0.7%	0.6%	-	-	-	-	-	-
intersection, no traffic light, turning right	0.7%	0.4%	-	-	-	0.3%	-	-	-
intersection, traffic light, straight ahead	12.0%	-	-	5.9%	0.3%	3.5%	1.3%	-	1.0%
intersection, traffic light, turning left	1.9%	0.4%	-	-	0.9%	0.6%	-	-	-
intersection, traffic light, turning right	-	-	-	-	-	-	-	-	-
curve	4.7%	1.9%	-	0.6%	0.4%	1.3%	-	-	0.4%
straight line, no crosswalk	52.7%	5.6%	2.3%	9.5%	8.1%	7.3%	10.7%	2.1%	7.1%
straight line, crosswalk no traffic light	0.7%	-	-	0.3%	-	0.3%	-	-	-
straight line, crosswalk traffic light	0.6%	-	-	0.6%	-	-	-	-	
others	6.7%	2.0%	1.4%	-	0.9%	1.5%	1.0%	-	-

A striking number of accidents happened to pedestrians approaching from the right of a driver with line-of-sight obstructions (proportion 15.1% of all, 10.7% of the severely injured/killed pedestrians). 20% of accidents were observed on straight line without any crosswalk when pedestrian was moving from left (9.5%) or from right with obstructions (10.7%)

ACCIDENTS OF PEDESTRIANS AT INTERSECTIONS/JUNCTIONS WITH TRAFFIC LIGHTS FOR PASSENGER CARS CONTINUING STRAIGHT AHEAD

80% of all collision velocities of the passenger cars were found at these locations (figure 1) up to 32 km/h, the corresponding driving speeds at the point of the reaction of the driver were determined up to 49 km/h (figure 2). 58.5 % of the pedestrians were lightly injured, with degree of severity MAIS 1, 14.3 % suffered from injures of a severity above MAIS 2 (MAIS 3+).

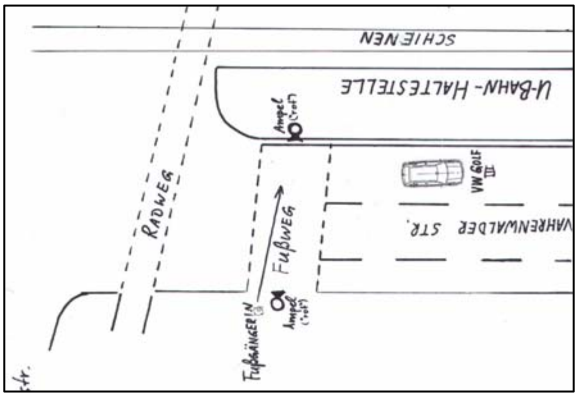

Figure 1. exemplary accident situation of this category

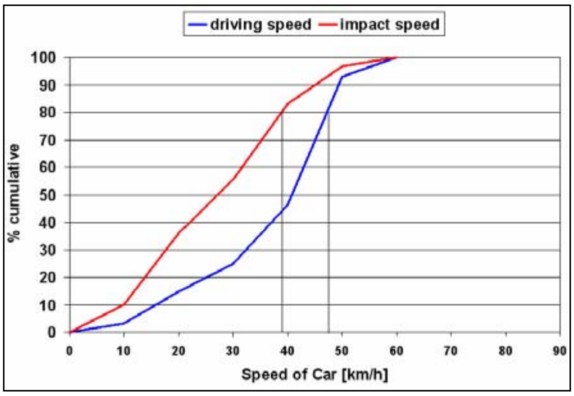

Figure 2. cumulative frequency distribution of the accidents as a function of collision speed and driving speed

Pedestrians under these collision conditions were injured at the head in 62.4% of the cases (figure 3). These injuries were particularly severe in 37.5 % of the cases (AIS 2+). A quarter of the injuries to the head (23.0%) originated from the impact of the head on the windshield, 10,3% from the impact of the head on the hood. At 49.8 % approximately half of all head injuries were caused by hitting the road surface.

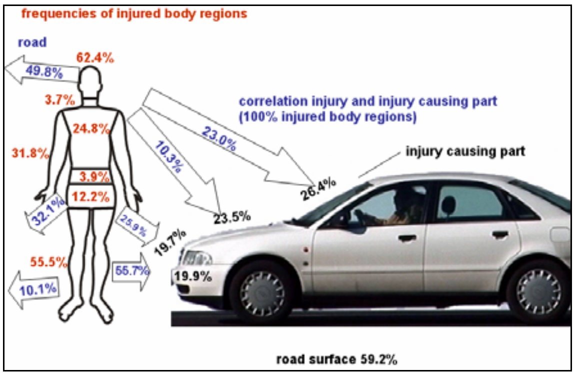

Figure 3. Frequency of injury of different areas of the body (100% all persons) with the corresponding proportions of the parts of the cars that have caused the injuries (100% all injured body regions).

In 55.5 % the legs were injured, in 56 % of the cases due to impact of the bumper. Injuries of the pelvis occurred in 12.2 % of the pedestrians, in 25.9 % of the cases they had been caused by the front edge of the hood, in 32.1% they were due to the secondary impact on the road surface. The windshield was the source of injury in 26.4% of all cases on these frequently seen accident situation category.

ACCIDENTS OF PEDESTRIANS AT INTERSECTIONS/JUNCTIONS WITHOUT TRAFFIC LIGHTS FOR PASSENGER CARS CONTINUING STRAIGHT AHEAD

These are accidents where pedestrians step into the road in the area of a junction or intersection, which has not been equipped with traffic lights or crossing aids (pedestrian crossing) (example figure 4).

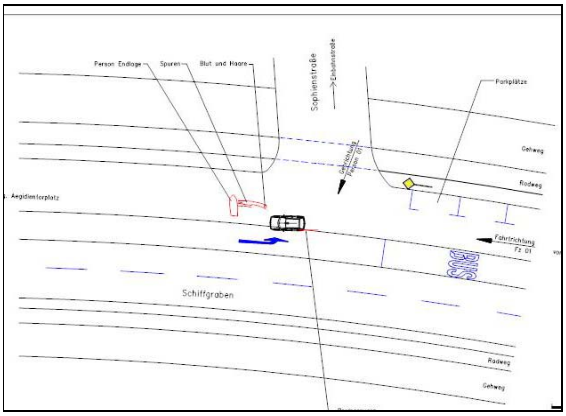

Figure 4. exemplary accident situation of this category

12.2% of the pedestrians involved in this situation suffered from severe injuries MAIS 3+ and 63.1 % were slightly injured (MAIS 1). 80% of all impact speeds could be registered with values of up to 32 km/h (figure 5).

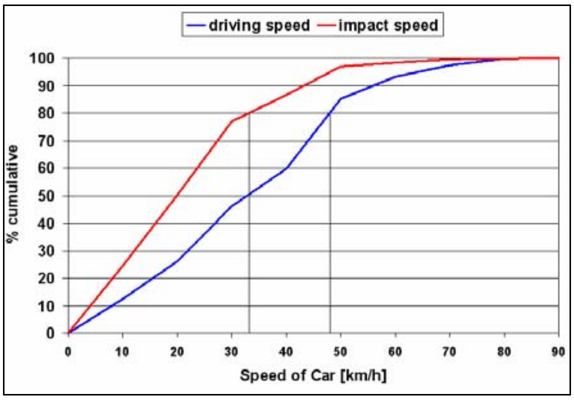

Figure 5. cumulative frequency distribution of the accidents with collision speeds and driving speed

52.8 % suffered from injuries to the head, of these approximately one third were severe, AIS 2+ (35 %). Injuries to the pelvis were recorded in 12.8 % of the cases and injuries to the legs in 63.8%, at 36% (AIS 2+) the latter were more frequently severe (figure 6).

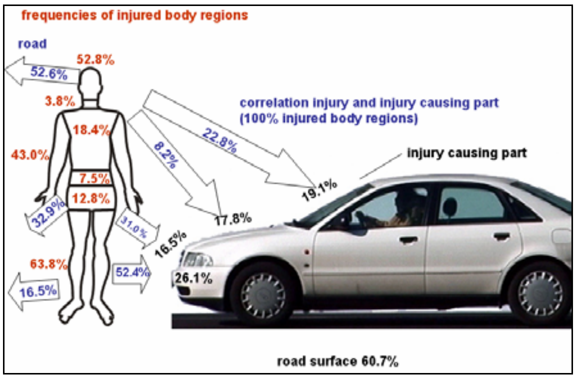

Figure 6. Incidence of injuries to the different parts of the body (100% all persons) with corresponding proportions of the parts of the cars causing these injuries (100% all injured parts of the body)

22.8% of the injuries to the head were caused by an impact on the windshield, which was responsible for the injuries of pedestrians in 19.1 % of the cases. A collision of the head with the hood turned out to be the cause of injuries in only 8.2 % of the cases, whereas 52.9 % of the injuries to the head could be attributed to an impact on the road surface. One third of the injuries to the pelvis (31 %) were caused by impacts with the front edge of the hood, another third (32.9%) by a secondary impact on the road surface.

ACCIDENTS OF PEDESTRIANS ON STRAIGHT ROADS WITHOUT SAFETY ELEMENTS

These are accidents, where pedestrians without line-of-sight obstructions step onto the road not equipped with crosswalks of lighting signs coming from the right (example figure 7)

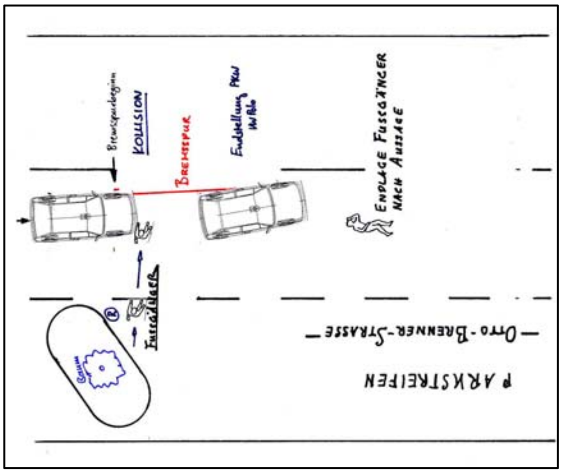

Figure 7. exemplary accident situation of this category

The 80-percent value of the collision speeds in these cases was situated up to 40 km/h (figure 8).

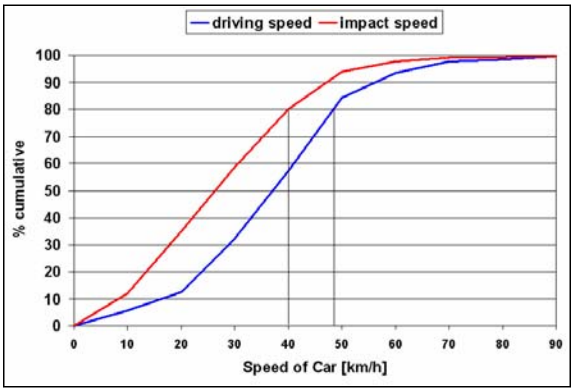

Figure 8. cumulative frequency distribution of the accidents with collision speeds and driving speed

11.1 % of the pedestrians were severely injured (MAIS 3+), 64.3 % were only slightly injured (MAIS 1). In 51.5 % of the cases the head was injured, in 70.1 % the legs and in 13.3 % the pelvis (figure 9). 39 % of the injuries to the head were severe (AIS 2+). Injuries to the legs were severe in only 24.6% of the cases and the injuries to the pelvis in 20.3%.

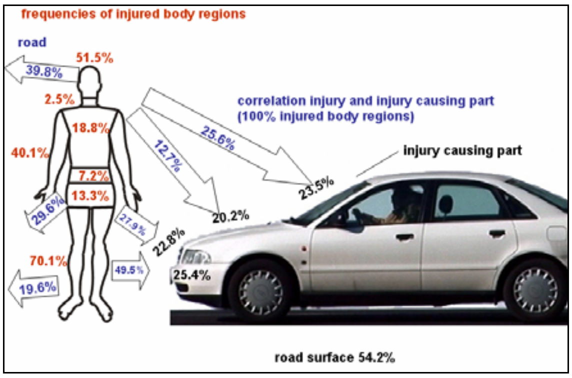

Figure 9. Incidence of injuries to the different parts of the body (100% all persons) with corresponding proportions of the parts of the cars causing these injuries (100% all injured parts of the body)

25.6 % of the injuries to the head resulted from an impact on the windshield, 20.2 % on the hood. An impact on the road surface was regarded as causal in only 39.8 % of the cases of an injury to the head. 27.9 % of the injuries to the pelvis were attributed to the front edge of the hood.

RELEVANCY OF THE SOURCES OF INJURIES ON VEHICLES FOR DIFFERENT ACCIDENT SCENARIOS

No significant differences of the injury situations could be seen for different places in the traffic environment. For all accidents, whether on straight roads or at intersections/junctions, nearly the same frequency distributions concerning injury severity, the injured body parts and the car parts causing the injuries apply. In all cases approximately 60 % of the pedestrians having collided with a car were slightly injured (MAIS 1), the proportion of severely injured pedestrians (MAIS 3 +) was always 11 or 12 %, always about one fourth of the pedestrians suffering from head injuries had hit the windshield. These, however, were at 40 % more frequently severe (MAIS 2+) on straight roads without special crosswalks than at intersections/junctions (34% MAIS 3+). The proportion of head injuries caused by an impact with the windshield was highest - at 25,6 % - for this accident location as well. Injuries to the pelvis also occur more frequently for this accident location (18.8 % as opposed to 12%), but they are not more severe.

In order to determine, if the injury situation differs in those locations, where an increased measure of caution towards pedestrians is required, only accidents on crosswalks or places equipped with traffic lights were evaluated and compared to the accidents of places without crosswalks (figure 10). It turned out that in these cases 80 % of the collision speeds up to 33 km/h and of the driving speeds at 47 km/h were slightly lower than in comparison with other accident locations. Thus the resulting injuries were also significantly less severe.

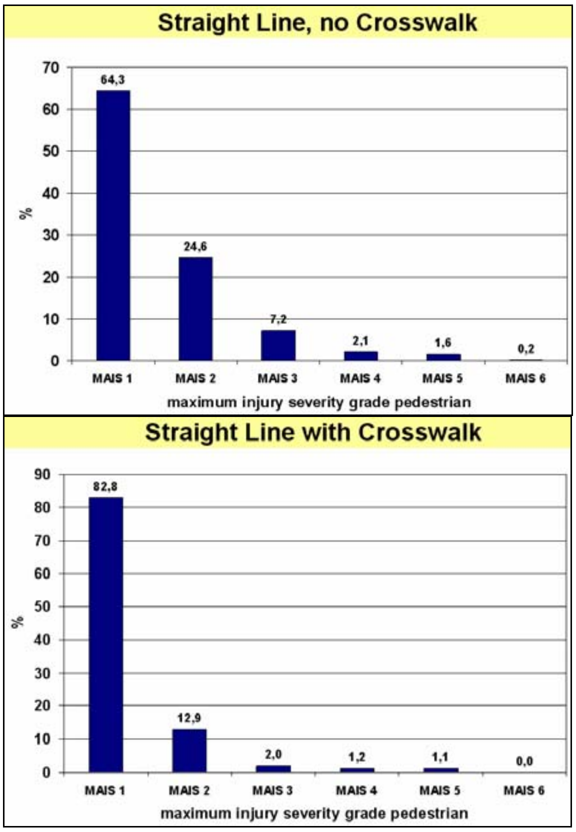

Figure10. Comparison of the frequency distributions of the severity of the injuries, MAIS, for accidents with pedestrians along straight stretches with and without crossings.

For accidents at crosswalks a lower injury severity for nearly all parts of the body is discernible (figure

11), for the head (23.2 %, AIS 2+) as opposed to 39 % at locations without crossing, for the pelvis (7.0% as opposed to 20.3%, AIS2+) and for the legs (10.9% as opposed to 24.6%, AIS 2+). At crossings, 33 % of the injuries to the head have been caused by an impact on the windshield and 51 % of the injuries to the pelvis have been caused be the front edge of the hood. However, figure 11 shows no reduced potential for injuries for legs and pelvis resulted for accident situations with crosswalks.

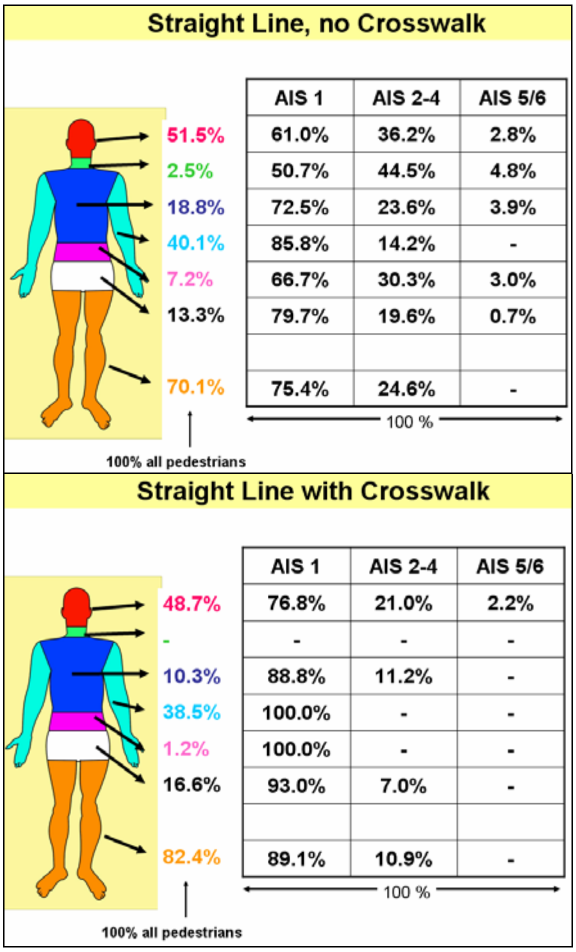

Figure 11. Frequencies of injured body parts and degrees of the severity of injuries MAIS at accident locations with and without crossing

Thus it seems that the measures on passenger cars undertaken lately for an optimized safety of pedestrians have been realized sufficiently extensively, as they are not influenced by the different accident scenarios and their differing incidences. As a rule, this is due to the fact that the pedestrian collides with the front of the car, which submits the person to pre-determined body kinematics of impact. Locally differing accident situations only result in differing impact velocities, if at all, and thus reduced severities of injuries, but as the study shows, these concern nearly exclusively the head, which mainly collides with the windshield, the defusing of which as a source of injury seems more than urgently required.

POTENTIAL OF PREVENTING ACCIDENTS BY TECHNICAL DESIGN OF THE SITE OF ACCIDENTS AND INNOVATIVE AUTOMOTIVE ENGINEERING ASSISTANT

On closer inspection of accident locations frequently involving pedestrians it was proven that a special, design-engineered crossing for pedestrians, by markings on the road or traffic lights, significantly lower the resulting severity of injuries. Thus it seems that local conditions, which draw the attention of the driver, do constitute a safety-increasing effect for pedestrians. Still, other solutions and developments of automotive engineering are possible, which can transmit a risk signal of a possibly occurring collision to the driver at an early stage.

If the time elapsed between the response and the collision itself is regarded - it was possible to determine these from the accident data provided - a significant difference between accidents with traffic lights or crossings and without such devices was noticeable (figure 12). Thus the maximum time that had elapsed between response and collision was 2.4 seconds for traffic lights and 2.1 seconds for crossings, whereas for accidents without traffic lights or crossings maximum values of up to 4 seconds occurred. This seems to leave sufficient space for a reduction of the response time and the braking distance.

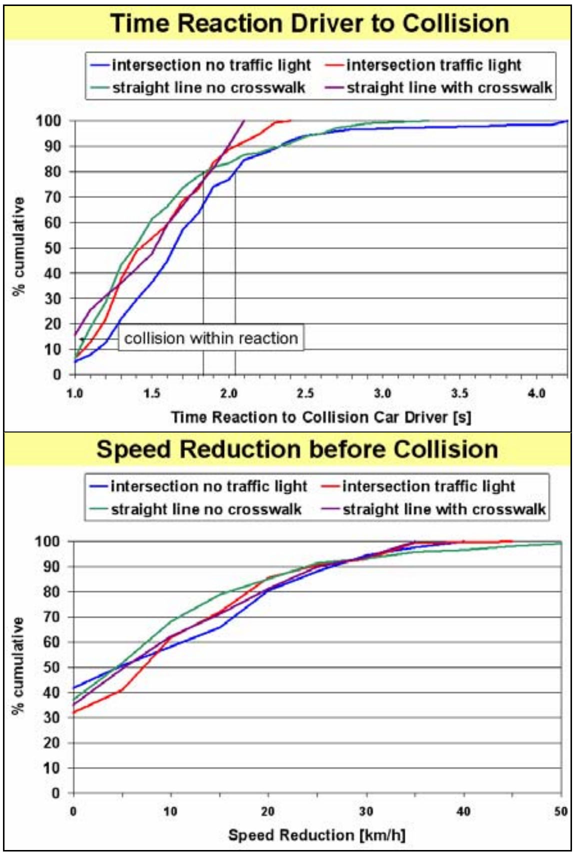

Figure 12. time duration from response to collision and corresponding reduction in velocity determined at the sites of accidents

90 % of all accidents at the sites of accidents investigated contained a reduction of the velocity of up to 25 km/h. The cumulative frequency distributions for the different sites of accidents show that this applies to all in nearly the same way. Approximately 40 % of the accidents do not contain a reduction in velocity before the impact.
It could be shown that an increasing reduction of the velocity and a reduced [response] time were linked to a reduction of the resulting severity of injury, MAIS (figure 13).

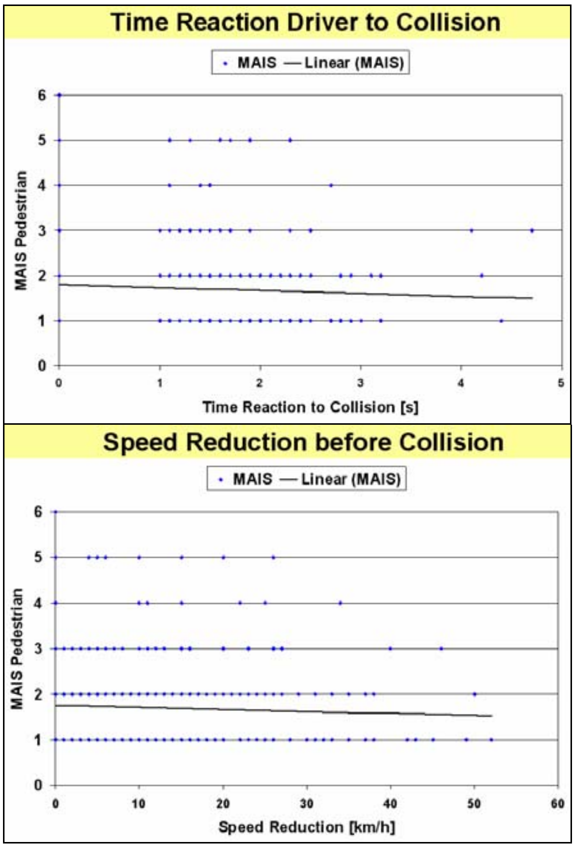

Figure 13. Correlation of severity of injury, MAIS, and time from response to collision as well as the resulting reduction in speed

If it would be possible to implement measures resulting in a reduction of the response time by 0.3 seconds for instance, an extension of the braking distance and an impact velocity reduced by approximately 9 km/h would follow. This can be seen in figure 14, referring to the accident population investigated here, and based on the correlation of MAIS and collision speed, the injury severity could be reduced by nearly half a degree. For instance at 50 km/h with an expected degree of severity of injury MAIS 2 to then 41 km/h with a MAIS of 1,8 (0.2 MAIS – points).

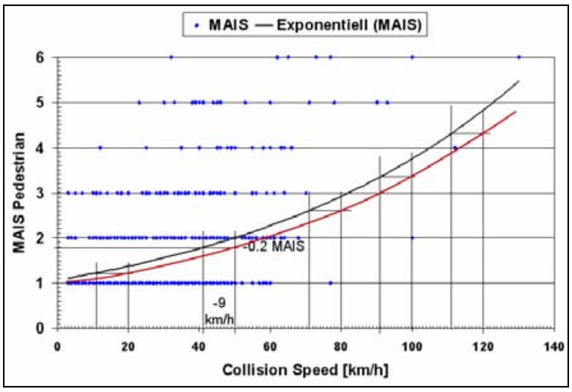

Figure 14. Correlation of the injury severity of all pedestrian-car collisions with the collision speed of the car with exponential regression line and representation of the expected reduction potential with a response time shortened by 0.3 seconds

CONCLUSIONS

For this study, 1107 statistically representative accidents between cars and pedestrians collected in GIDAS (German-In-Depth-Accident-Study) were evaluated. From this population the most frequent accident situations for pedestrians involved in accidents with passenger cars were extracted. It turned out that 90 % of all collisions between cars and pedestrians occur in three major accident situations, at straight roads without safety features like crosswalks or special lighting systems, at intersections/junctions without traffic lights und at intersections/junctions with traffic lights. 20 % of all accidents occur at straight roads without any safety features for the pedestrian crossing the street from the left (9.5%) as well as with a line-of-sight obstruction for the driver of the passenger car when crossing the street from the right (10.7%).
No clear difference could be shown in the injury situation of pedestrians having been hit by a car in different locations of the traffic environment; always approximately 60 % were slightly injured, MAIS 1, the proportion of MAIS 3+ was always between 11 and 12 %. This is following from the kinematics of the course of the collision is dominated by the position of the pedestrian in front of the car and the resulting bodily movement across the hood with subsequent sliding or flying phase. As these are largely collisions of the front end of the car with a pedestrian, the resulting injury based on the classical configuration of pedestrian and car consists or injury severity MAIS and injury frequency percentages nearly in the same manner, the differences are partly margin. The influence of accident locations is mainly focused to the speed level of the collision. Thus this study was able to show that for accidents occurring at locations with safety features for pedestrians, such as crossings or traffic lights, the distribution of injury severity occurring here resulted more frequently in slightly injured persons than for

locations without any safety features. The study also showed that at locations with crossing features, injuries to the head occur less frequently, and also legs and pelvis are less severely injured. In the course of the study it was shown that the time that elapsed from the moment of reaction until the collision lasted up to 2 seconds in 80 % of the cases, the speed reduction to the point of collision was up to 25 km/h in 80% of the cases; up to approximately 40% of the cars did not reduce speed until the collision. Thus a significant potential for further reductions of the collision speed can be made out. The study postulated that a reduction of the response time by 0.3 seconds, for instance, would result in a collision speed reduced by about 9 km/h for the car and that the expected injury severity for the accident population regarded could be reduced by about 10 % by using the AIS Scale as linear and carried out an exponential regression analysis on injury vs. speed relation. The study was thus able to confirm the expected potential of a brake assist system based on an analysis of accidents. In addition, the result of this study can support the evaluation of different accident scenarios involving pedestrians regarding the different technical assisting systems applicable. For instance, assistance systems that are constantly monitoring the driving situation ahead would be able to reduce response time in accidents involving pedestrians walking in the same or opposite direction facing the vehicle. This would cover 12% of all accidents involving pedestrians and 18% of all pedestrians injured MAIS 3+ as a target group. Also, for pedestrians crossing the road from the left, technical information systems seem sensible in order to reduce response times, as these constitute one third of all accidents involving pedestrians (31% of all and 33% of all MAIS 3+).

LITERATURE

[1] Brühning, E., Otte, D., Pastor, C.; 30 Jahre wissenschaftliche Erhebungen am Unfallort für mehr Verkehrssicherheit, Zeitschrift für Verkehrssicherheit 51, 175-181, 2005

[2] StBA- Statistische Daten der Verkehrsunfälle in Deutschland 2005
Stat. Bundesamt Wiesbaden, Fachserie P, Reihe 7, Verlag Metzler-Poeschel, 2006

[3] Commission of the European Communities; Proposal for a Directive of the Euopean Parliament and of the Council relating to the protection of pedestrians and other vulnerable road users in the event of a collision with a motor vehicle and amending Directive 70/156/EEC, Brussels, 2003

[4] Otte, D.; The Accident Research Unit Hannover as Example for Importance and Benefit of Existing In Depth Investigations, SAE-Paper No. 940712, Proc. International SAE Congress, Detroit/USA, 1994

[5] Pfeiffer, M., Schmidt, J.: Statistical and Methodological Foundations of the GIDAS Accident Survey System, 2nd ESAR Conference, Hannover, 2006

[6] FGSV, Forschungsgesellschaft für Straßen- und Verkehrswesen: Erfahrungen mit dem dreistelligen Unfalltypenkatalog, Arbeitsgruppe Verkehrsführung und Verkehrssicherheit, Arbeitsausschuß Verkehrsunfälle, Arbeitspapier Nr. 24, 1990

[7] American Association for Automotive Medicine: The Abbreviated Injury Scale - Revision 98, American Ass. f. Automotive Medicine., Morton Grove, Illinois (USA) 1998

[8] Otte, D.; 3-D Laser systems for scaled accident sketches and documentation of the traces after traffic accidents as basis of biomechanical analysis, Ircobi Conference, 435-438, 2005