Proposal for a Test Procedure of Assistance Systems regarding Preventive Pedestrian Protection

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ABSTRACT

This paper is showing a proposal for a test procedure regarding preventive pedestrian protection based on accident analysis.

Over the past years pedestrian protection has become an increasing importance also during the development phase of new vehicles. After a phase of focusing on secondary safety, there are current activities to detect a possible collision by assistance systems. Such systems have the task to inform the driver and/or automatically activate the brakes. How practical is such a system? In which kind of traffic situations will it work? How is it possible to check the effectiveness of such a system? To test the effectiveness, currently there are no generally approved identifiable procedures. It is reasonable that such a test should be based on real accidents. The test procedure should be designed to test all systems, independent of the system's working principle. The vFSS group (ad**v**anced **F**orward-looking **S**afety **S**ystems) was founded to develop a proposal for a technology independent test procedure, which reflects the real accident situation. This contribution is showing the results of vFSS.

The developed test procedure focuses on accidents between passenger cars and pedestrians. The results are based on analysis results of in-depth databases of GIDAS, German insurers and DEKRA and added by analysis of national and international statistics. The in-depth analysis includes many pre-crash situations with several influencing factors. The factors are e. g. speed of the car, speed of the pedestrian, moving direction and a possible obscuration of the pedestrian by an object. The results comprise also the different

situations of adults and children. Furthermore, they include details regarding influence of the lighting conditions (daylight or night) especially with respect to the accident consequences. In fact, more accidents happen at daylight, but fatal accidents are more often at night.

A clustering of parameter combinations was found which represents typical accident scenarios. There are six typical accident scenarios which were merged in four test scenarios. The test scenarios are varying the starting position of the pedestrian, the pedestrian size (adult or child) and the speed of the pedestrian, whereas the speed of the car will not be varied. To ensure the independency from used sensing technologies it is necessary to use a suitable dummy. For example, if sensors are based on infrared, the dummy should emit the temperature of a human being.

The test procedure will identify the collision speed as the key parameter for assessing the effectiveness of the tested system. The collision speed is defined as the reduction between initial test speed of the car and impact speed. The assessment of the speed reduction value regarding the safety benefit, however, will be part of a separate procedure.

INTRODUCTION

The pedestrian protection has become an increasing importance. In the first phase there was a focus on secondary safety which led to intensified activities in this area at the front of the vehicles. The extended possibilities of sensing technologies and improved performance of data processors in combination with better knowledge about the accident causes allows the development of driver assistance systems also for pedestrian accidents.

An advanced driver assistance systems (ADAS) is not only designed to avoid an accident. It includes also the possibility to reduce accident consequences by e.g. reducing the impact speed. There are different possibilities which could be the warning of an inattentive driver or an automatic braking manoeuvre. The action of an ADAS depends on the traffic situation and also on the implemented philosophy. Just the philosophy of the ADAS is an important point.

Depending on the time to collision the system has the task to inform the driver and/or to activate the brakes. How practical is such a system? In which kind of traffic situations will it work? Is such a system fulfilling the expectations of a driver?

So far an independent test standard to verify the system reliability and effectiveness is missing. Specific tests for special systems cannot generate comparable results. Thus a test standard mirroring real accidents is required.

In the future there will be definitely procedures to test ADAS. Based on this fact several companies decided to work together to develop proposals for test procedures for selected ADAS. The companies Allianz Center for Technology (AZT), Audi, Federal Highway Research Institute of Germany (BASt), BMW, Daimler, DEKRA, Ford, GDV, Honda, KTI, Opel, Porsche, Toyota and Volkswagen work together in the working group vFSS (Ad**v**anced **F**orward-looking **S**afety **S**ystem). The target of the group is to develop proposals for test procedures for forward-looking safety systems based on the results of accident analysis. The test procedure should be independent from used sensing technologies. The first focus of vFSS is on preventive pedestrian protection and forward collision warning/avoidance systems. This contribution is explaining how the proposal of test protocol regarding preventive pedestrian protection was developed.

DATABASIS

The results of the vFSS accident analysis are based on different sources. vFSS used published from European projects as well as public available statistics from Germany. The used In-Depth databases were GIDAS, UDV, and AZT supplemented by analysis of the DEKRA Database. These are described below.

Official Road Traffic Accident Statistics

Federal statistics are continuously maintained on accidents in which fatalities or material damage have been caused as a consequence of road traffic on public roads and open spaces. They serve to produce an up-to-date, comprehensive and reliable database on the structure and development of road accidents; Section 1 (Law on Statistics of Road Traffic Accidents) [1]. The published German statistics are prepared by the Federal Statistical Office of Germany (StBA).

GIDAS Database

GIDAS (German In-Depth Accident Study) is a joint project conducted by the Federal Highway Research Institute (BASt) and the Research Association of the Automotive Technology (FAT) of the VDA. The project makes available detailed and statistically representative data of real-life road accidents in Germany. The accident location is in the conurbation of Hanover or Dresden. The accidents are collected during a survey shift (specific random sample scheme) if at least one person injured.

The GIDAS project has recorded around 3,000 individual facts on each of approximately 2,000 accidents annually since 1999. The GIDAS Database currently comprises 19,000 accidents with 33,500 involved vehicles and a total of 47,500 persons.

The defined random sampling procedure and the use of weighting factors enables the GIDAS Database to give a representative reflection of those national accident statistics involving personal injury. The number of cases is so high that statistically significant results can be achieved. The high level of detail of the cases also enables in-depth investigations.

Accident Database of German Insurers Accident Research

The evaluated case material of the UDV is primarily comprised of the claim files of the insurers that are routinely drawn on a random sampling basis from the total number of all liability damage cases in Germany for the purpose of conducting accident research. The accidents here are accidents involving personal injury and damage of at least €15,000. They took place during the period 2001 - 2006.

The accident database (UDB) of the UDV contains 4,500 accidents with 8,200 victims.

Accident Database of Allianz Center of Technology

The Accident Database of the Allianz Technology Center (AZT) is comprised of the claim files of the Allianz insurance. The claims files are selected on a random sampling basis from the total number of the 1.5 million yearly liability damage cases. The cases used are accidents involving personal injury.

The accident database of the AZT contains more than 20,000 accidents containing 1,750 with involved passenger cars.

DEKRA Accident Database

DEKRA maintains a national network of road accident analysis experts. Accident reconstruction reports are prepared primarily for the courts, public prosecution services, police and insurance companies. DEKRA Accident Research has access to these reports. The cases were selected on a random basis, analysed and added to an accident database..

The database currently contains about 3,000 accidents.

ACCIDENT ANALYSIS

The accident analysis is primarily based on German accident data. The results of the analysis are supplemented by existing results from the UK and results of publications coming from the European project SafetyNet [3].

General Statistics

In 2008 in Germany all together 320,614 accidents leading to personal injuries were registered. 413,524 persons were injured within these accidents (4,477 fatally injured + 70,644 severely injured + 338,403 slightly injured persons). Most of the accidents occurred at daylight (Figure 1, n=299,526). The share of persons injured during the night is accounting for less than one third (Figure 2, n=113,237). Thus three out of four persons get injured during daylight. A view to the pedestrians shows a ratio of two injured pedestrians at daylight to one during night time (22,272 at daylight in relation to 11,151 at night). An additional view to the fatally injured pedestrians shows a differing ratio. There were 256 fatalities at daylight in relation to 397 under dark lighting conditions (Figure 3 + Figure 4).

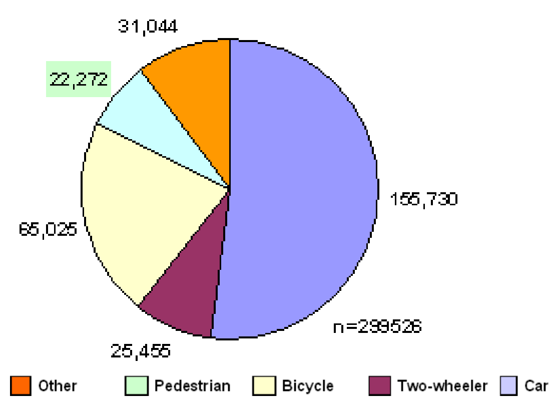

Figure 1 Persons injured by road accidents under daylight conditions in Germany 2008[2]

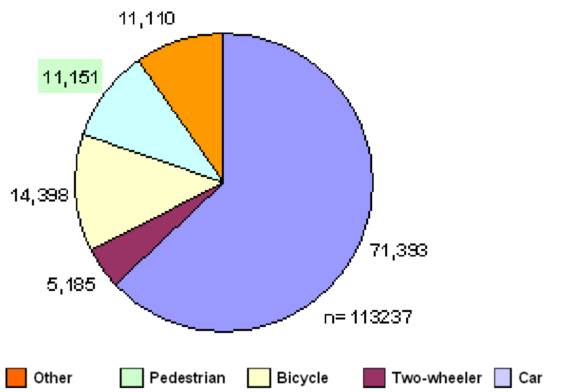

Figure 2 Persons injured by road accidents under night conditions in Germany 2008, source StBA

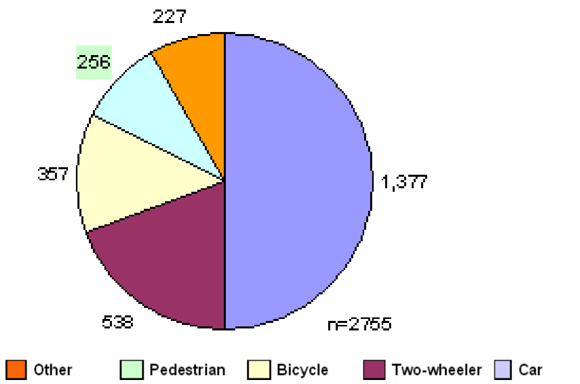

Figure 3 Road accident fatalities under daylight conditions in Germany 2008, source StBA

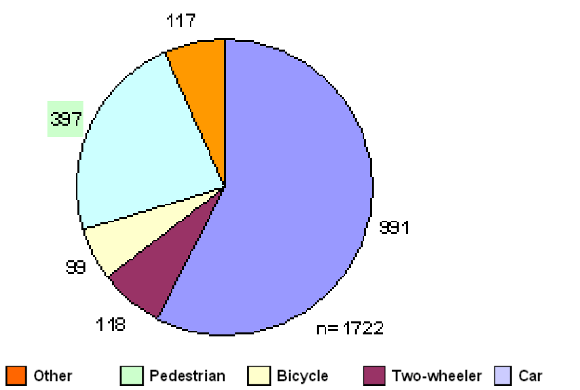

Figure 4 Road accident fatalities under night conditions in Germany 2008, source StBA

Analysing the German 2008 road accident statistics for the location of the fatal accidents under night conditions the rural areas show the highest frequency (Figure 6 + Figure 5, n=1,000). The number of fatalities in urban areas is accounting for 490 and thus roughly half of the urban figures. 231 persons were killed on motorways. They add to approximately one quarter of the urban figures. Looking to the pedestrian fatalities they show a clearly differing pattern. Nearly 50% of all fatalities in urban areas under night conditions are pedestrians (241 of 490), whereby the share in rural areas is less than one seventh (130 of 1,000).

The German figures of 2008 also show the significantly higher share of fatal injured pedestrian in the winter months from November to January with long nights and short days, Table 1. In the monthly average 82 pedestrians were fatally injured in November, December and January. This is nearly twice the figure of the remaining months with 45 fatalities. 182 of the 246 November to January accidents occurred under night conditions (74%).

The European pedestrian accident statistics show a similar correlation. The mean value of 18 European countries for pedestrians killed under night conditions is 52.6%, Figure 7.

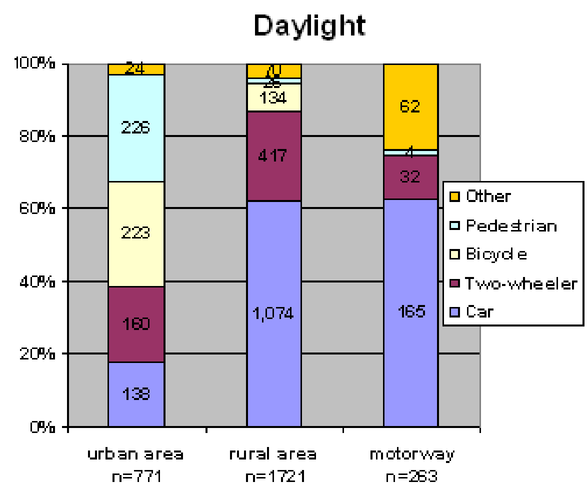

Figure 5 Road accident fatalities under daylight conditions split to the different locations in Germany 2008, source StBA

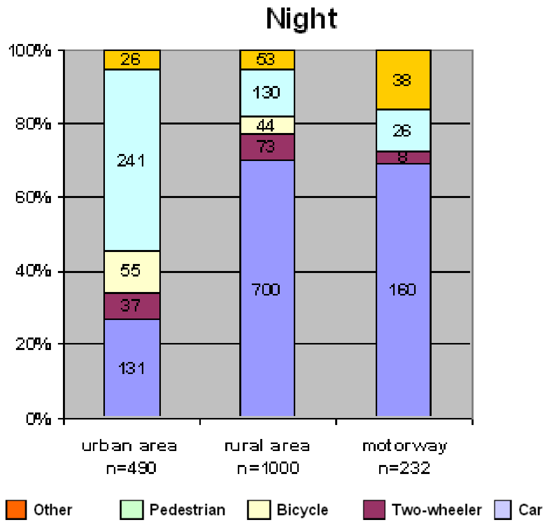

Figure 6 Road accident fatalities under night conditions split to the different locations in Germany 2008, source StBA[2]

Table 1 Distribution of fatally injured pedestrians in Germany 2008, source StBA

	2008	
Total	653	100%
Nov … Jan	246	38%
Monthly mean value Feb … Oct	45	
Monthly mean value Nov … Jan	82	
Nov … Jan	246	100%
Darkness	182	74%
Age >65y.	135	55%

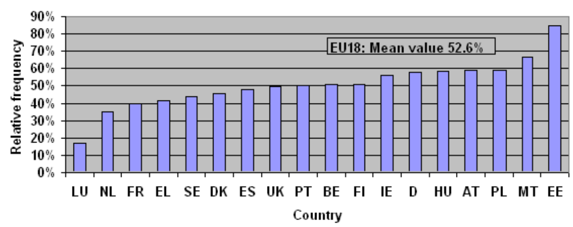

Figure 7 Share of fatally injured pedestrians under night conditions for 18 European Countries [3]

In-Depth Analysis

The results of GIDAS, UDB, AZT and DEKRA complete the knowledge given by the reports.

All sources show nearly the same typical scenarios for the accidents between passenger cars and pedestrians. These scenarios include crossing with and without obstruction. Some also mention "Turning accidents" and/or "Accidents along the carriageway". All results show that the "crossing accidents without obstruction" include the highest share,Table 2. The crossing accident with obstruction is on the second rank in most analysed sources.

As shown above the lighting conditions play an important role. Roughly 60% of the GIDAS and UDV car against pedestrian accidents occurred under daylight conditions, as shown in Figure 8. The higher level of accident severity under night conditions is corroborated by the GIDAS data. Looking at the crossing accidents the share of fatalities doubles from daylight to night conditions, Figure 9. The total number of crossing accidents under daylight accounts for about twice the figure as under night conditions.

Table 2 Shares of selected accident situations of different data sources (100% all frontal collisions between passenger cars and pedestrians), source GIDAS, UDB, AZT [4].

	GIDAS n=1,065	UDV n=243	AZT n=30	UK (APROSYS)
Crossing without obstruction	60	59,8	71	58,6
Crossing with obstruction	27	11,0	13,2	17,9
Turning	7	21,2	10,5	
Along carriageway in/against direction	3	8	5,3	11,1

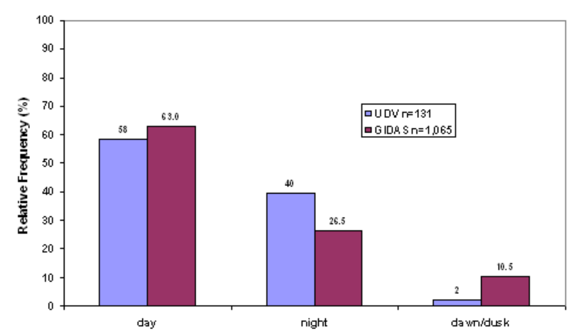

Figure 8 Distribution of lighting conditions of UDV and GIDAS car-pedestrian accidents

The most frequent contact area in car to pedestrian collisions is the vehicle's front (60%). The left (right) side of the car is hit in 11% (12%). The rear end collisions account for 13%. Most of the pedestrians (92%) hit by the vehicle's front are crossing a road, 59.8% without a view obstruction and additional 11% with a view obstruction. Some pedestrians (8%) are hit by a car while they are walking along the carriageway. The remaining 21.2% of the pedestrians collide with a turning car. The working group vFSS is focusing the frontal collisions, which are the basis for the following analysis. The analysis of the UDB led to the accident scenarios displayed in Figure 10.

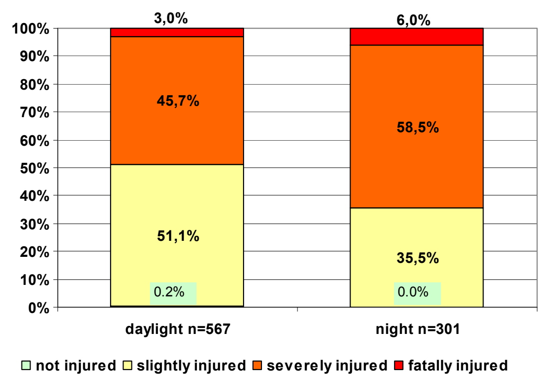

Figure 9 Injury severity of the pedestrians in crossing accidents, source GIDAS

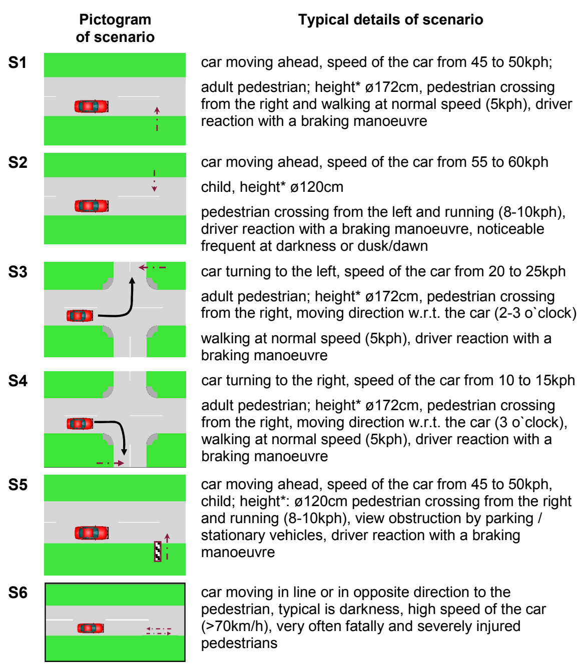

Figure 10 Typical car to pedestrian accident scenarios, source UDB

A special analysis carried out within the German "AKTIV" project resulted in three typical accident scenarios. The GDV scenarios S1 and S2 are summarized in AKTIV scenario F1, the scenarios S3 and S4 in F3. The scenario S5 is included in F2.

Remarkable is the high proportion of scenario S2 occurring under night conditions, Figure 10. The details of the scenarios mentioned in are a summary of the total results. The mentioned figures for speeds and body heights are the typical values. The spread of course is a lot larger.

The risk of injury severity varies from scenario to scenario, Table 3. This table is only showing the shares of the listed scenarios. There are missing figures, which are caused by not listed scenarios. The scenario S2 includes 60% of the fatally, 30% of the severely and 18% of the slightly injured of the pedestrians. Together the scenarios S1 and S2 cover two third of all severe or fatal injuries caused by a frontal collision with a passenger car.

Table 3 Share of accident scenarios subdivided into the accident consequences, source UDB

Scenario	share of injuries		
	fatally injured	severely injured	slightly injured
S1	16	39	24
S2	60	30	18
S3	0	13	13
S4	0	3	0
S5	15	6	4

The kind of obstruction is often another vehicle. The GIDAS data show a share of 42.5% of accidents with a sight obstruction including 30.5% obstructions by a vehicle, Figure 11. There is an important question. Was the driver able to brake and if yes how strong? The analysis show roughly the same share of braking manoeuvres at day and night, but the achieved deceleration is lower during the night, Figure 12. Combined with the higher initial speeds (Figure 13) the impact speeds at night are clearly higher, Figure 14. This is of course one important influencing factor regarding the higher accidents consequences at night.

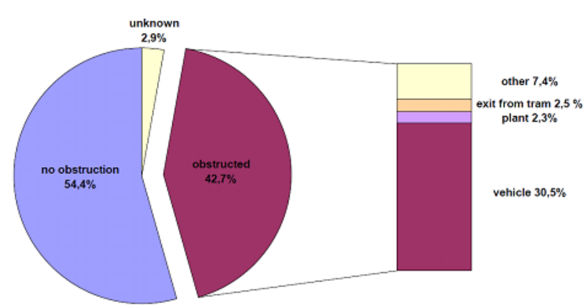

Figure 11 Share and kind of obstructions of car against pedestrian accidents, source GIDAS.

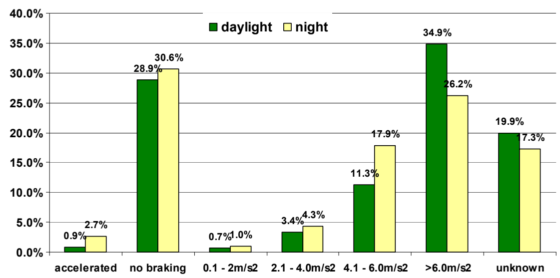

Figure 12 Deceleration of passenger cars in crossing accidents (n=868), source GIDAS

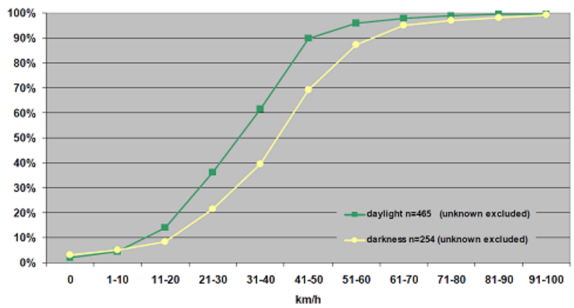

Figure 13 Initial speed of passenger cars in crossing accidents, source GIDAS

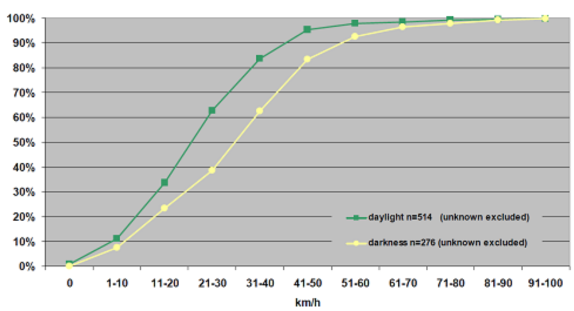

Figure 14 Impact speed of passenger cars in crossing accidents, source GIDAS

The analysis of the pre-crash movement of the pedestrians displays that they are using several ways to reach the crossing point, Figure 15. Many of the pedestrians were standing at the borderline (41% on the right + 27% on the left side). Some walked along the sidewalk (right 7% + left 2%) and a small percentage (5%) moved at right angles to the lane. An important value for a possible sensing system is the time of the first visibility of the pedestrian and the collision (Time to Collision=TTC), Figure 16. It is obvious, that many of the just mentioned standing pedestrians are visible for a long time. Therefore a high percentage for TTC=3.0s is comprehensible. Spreading the TTC-values to covered and uncovered pedestrians leads for uncovered pedestrians to a share of 70% visible pedestrians at TTC=3.0s, Figure 17.

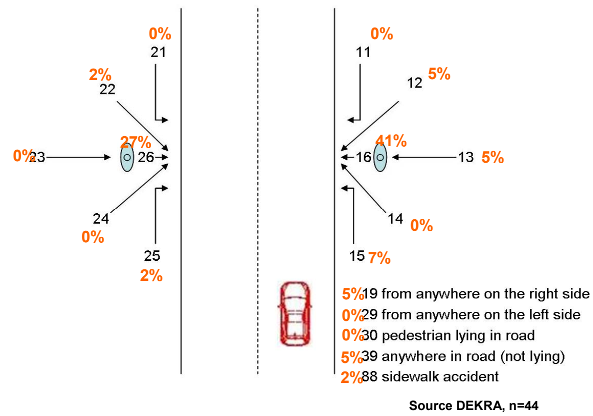

Figure 15 Pre-crash movement of pedestrians in car to pedestrian accidents, source DEKRA

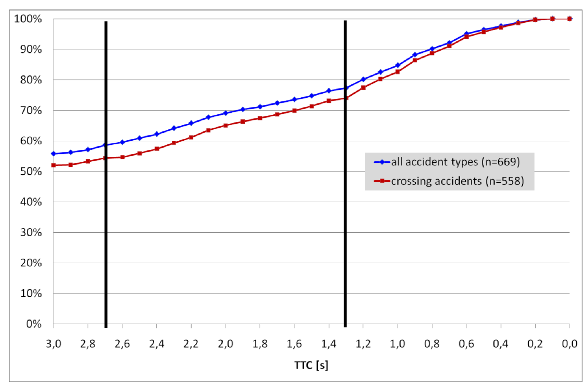

Figure 16 Cumulative frequency of TTC from the first point of pedestrian's visibility, source GIDAS

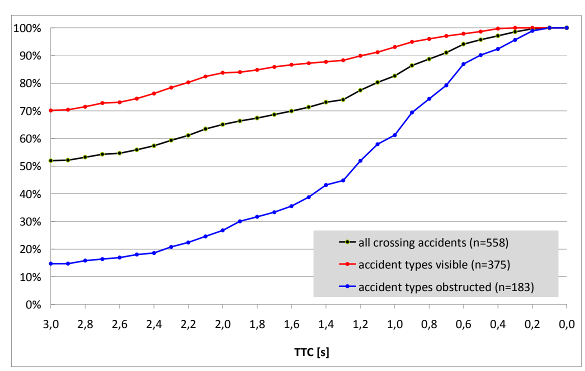

Figure 17 Cumulative frequency of TTC from the first point of pedestrian's visibility split in accident situations with and without obstruction, source GIDAS

TEST PROCEDURE

The accident analysis includes many interesting results. The task is to transfer these results in a proposal for a test procedure. The accident scenarios shown in Figure 10 are the basis of this procedure. The first point is to filter the most important ones.

An ADAS regarding pedestrians will get a symmetric layout, therefore the scenario S2 (pedestrian crossing from the left side) can be included in S1 (pedestrian crossing from the right side). The turning scenarios S3 + S4 are included in S5, because the sensing system will work as if the pedestrian is covered on a straight road. Due to the large variety of single situations covered by scenario S6 and the comparable small absolute figures the scenario S6 was not included in the test procedure.

The main factors to be considered within the test scenarios are the pedestrian's body height, walking speed and the presence or absence of an obstacle. This results in the four test scenarios (TS1 to TS4) shown in Figure 18 to Figure 21. The speed of the passenger car is fixed to 40km/h.

The TTC values of TS1 + TS2 are fixed to 1.3s, the TTC for TS3 + TS4 are 2.7s. The values were won within the accident analysis.

It is important to ensure that the procedure is independent from the sensing technology. This includes that the used pedestrian dummy is visible e.g. for a radar or an infrared sensor. It implements not, that there is one dummy which is covering all sensor systems. It is only necessary, that the testing institute has a dummy with the questioned attribute(s).

To avoid a systems application targeting a good test performance additional tests are foreseen. Those are developed in the scope of covering side influences like night conditions, other pedestrians walking along the side walk, or another car speed. The tested systems have to work reliable within these parameters.

The system test of the vehicle should be done 10 times for each proposed test scenarios I to IV. The system has to warn or to brake. The tests will deliver 10 valid measured values of the collision speed. The result of the test procedure will be the speed reduction (V_{RED}), which is the difference between test speed (40 km/h) and impact speed. The results of the V_{RED} will be used in a separate assessment procedure to receive a comparative value.

TS1

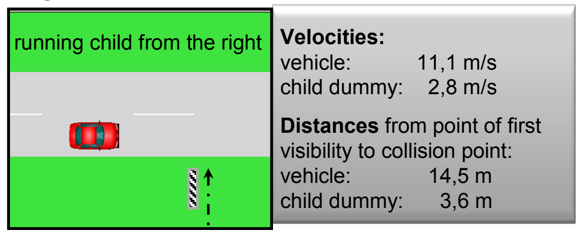

Figure 18 proposed procedure for covered running child

TS2

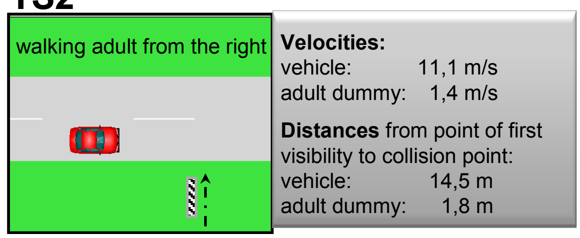

Figure 19 proposed procedure for covered walking adult

TS3

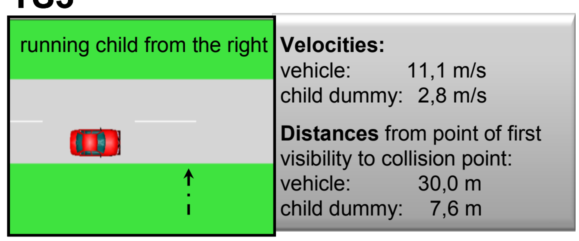

Figure 20 proposed procedure for uncovered running child

TS4

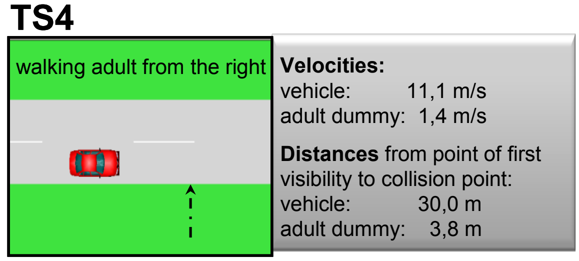

Figure 21 proposed procedure for covered walking adult

SUMMARY

Driver assistance systems have an important impact on road safety. With different system concepts and new working principles an independent test procedure is required to verify the benefit potential and to get comparable values.

To define such a test procedure several vehicle manufacturers, insurance companies, KTI and DEKRA, BASt found the vFSS working group. One main focus was set on systems for preventive pedestrian protection. A comprehensive analysis of the accident occurrence was carried out to figure out high risk situations to be covered by the test procedure.

Within the working group four test scenarios were defined. The test layout was designed in a way the full range of the different systems can be assessed. Thus also systems with a comparable low performance can pass the test albeit with a lower ranking. This is to not limit the tests to the premium class systems only. That way the systems can enter all vehicle classes and thus ensure a broad market penetration.

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