BENEFIT ASSESSMENT OF FORWARD-LOOKING SAFETY SYSTEMS

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ABSTRACT

Forward collisions are still the most relevant scenarios in the German accident situation with personal damage. Therefore forward-looking safety systems have a high potential to reduce the number of casualties or to mitigate their injury severity.

To assess the benefit of these forward-looking safety systems, a new benefit assessment method will be presented in this paper. The method uses real accidents out of the GIDAS. Additionally to the collision speed of the vehicle and other impact parameters, all accidents in GIDAS are reconstructed regarding the movement of all participants in the last seconds prior to the impact. This movement is used to simulate the accident initiation phase with and without the influences of forward-looking safety systems. Subsequent to this simulations the differences with and without safety system could be compared case by case. The results could be converted into different absolute measures like reduction of fatalities or severely injured pedestrians, using injury severity functions.

The results of this study are different correlations, depending on the system functionality, between the reduced impact speed due to braking prior to the crash and the assessed mitigation on injury severity. The results of the single case simulation could be summarized to access the overall benefit of these systems in the whole accident scenario.

With this method it is possible to assess the expected benefit of future safety systems or equally suitable to evidence the benefit of current safety systems on the market.

The papers show the detailed procedure of the method and some examples of usage the results.

GIDAS

For this paper accident data from GIDAS (German In-Depth Accident Study) was used. GIDAS is the largest in-depth accident study in Germany. The data collected in the GIDAS project is very extensive, and serves as a basis of knowledge for different groups of interest. Due to a well defined sampling plan, representativeness with respect to the federal statistics is also guaranteed. Since mid 1999, the GIDAS project has collected on-scene accident data in the areas of Hanover and Dresden. GIDAS collects data from accidents of all kinds and, due to the on-scene investigation and the full reconstruction of each accident, gives a comprehensive view on the individual accident sequences and its causation.

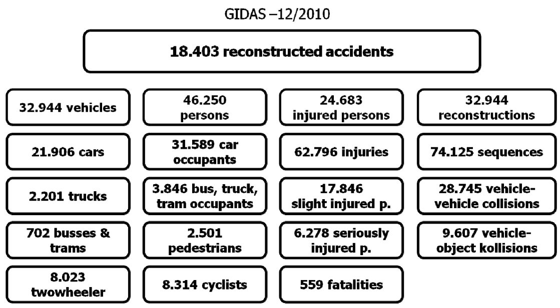

Figure 1 – extent of GIDAS real accident database

As described in Figure 1 more than 18.000 complete reconstructed accidents are available in GIDAS.

The project is funded by the Federal Highway Research Institute (BASt) and the German Research Association for Automotive Technology (FAT), a department of the VDA (German Association of the Automotive Industry). Further information can be found at http://www.gidas.org.

POTENTIAL OF FORWARD-LOOKING SAFETY SYSTEMS

Especially for the potential of forward-looking safety systems not only front to rear accidents are of interest.

Depending on the critical situation of each accidents, forward-looking safety systems could have potential for accidents that causes during

- turning off scenario
- turning into scenario
- crossing of pedestrians
- resting traffic situations
- longitudinal traffic scenarios.

The aspect of guilty or not could be in- or excluded in the analysis. For the used method in this study the question of guilt was not separated. So it is assumed for instance, that a system operates even when a critical situation occurs, independently of the question, who have had the right of way in the situation.

Following this aspects out of GIDAS nearly 56% of all first impacts of cars are frontal impacts, which could be defined as principally addressed by forward-looking safety systems. These principally addressed cases certainly include accidents where forward-looking safety systems will have partly, marginal or sometimes also no effect, but nevertheless this ratio shows the high priority of forward-looking vehicle safety systems to further reduce accident and injury severity.

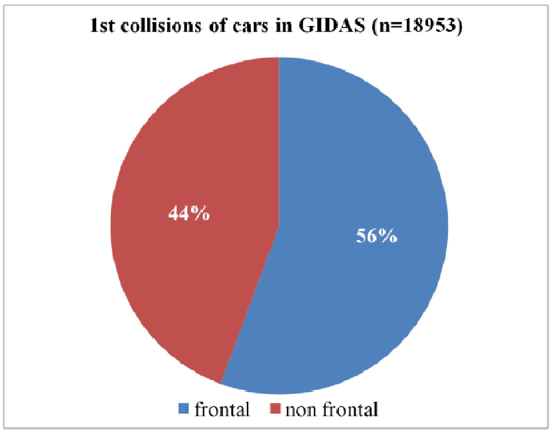

Figure 2 – First impacts of cars

Figure 3 shows the number of pedestrian which impact frontal to the car. This ratio of 71% is much higher than the average of all collision partners of cars. It shows therefore the very high priority of forward-looking safety systems in car to pedestrian accidents.

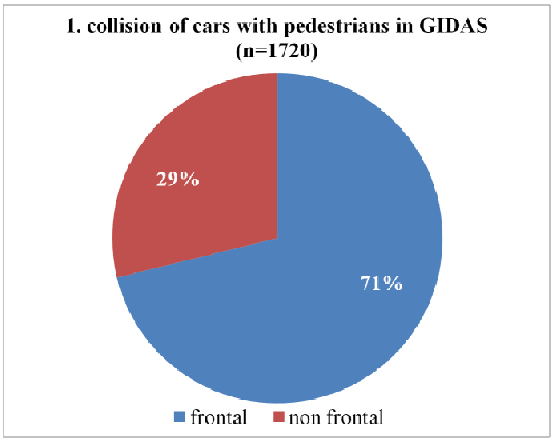

Figure 3 – First impact of cars with pedestrians

For a better description of the benefit assessment method in this paper, all further analysis and results are referred only to car to pedestrian accidents.

METHOD TO ESTIMATE THE SYSTEM EFFECTIVENESS

In the past different methods were used to estimate the benefit of safety systems. Especially for forward looking safety systems, methods using simulation are coming more and more important. These mainly prospective analyses have the advantage, that already system in a status of an idea could be assessed regarding the benefit in real world accidents.

Prospective case by case analysis

Prospective case by case analyses mostly using real world accident data. For this study the data from GIDAS effective 12/2010 was used. In Figure 4 the principle methodology of a prospective case by case analysis is shown.

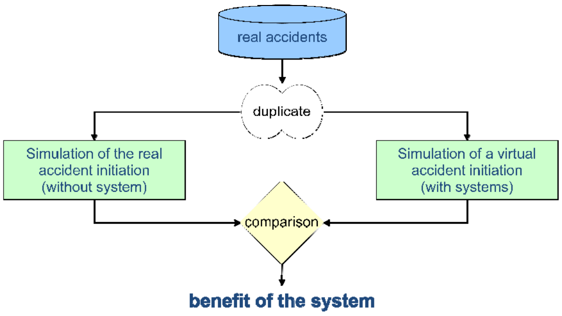

Figure 4 - Prospective case by case analysis

Every accident initiation phase will be simulated in detail to gain knowledge about the circumstance which leads to this accident. After that, the complete functionality of the system or system idea will be implemented in the simulation process. In this step a virtual accident initiation will be simulated, which includes all changes due to the system influence. Afterwards the differences between the real and the virtual accident simulation will be compared. These differences show directly the benefit of the system in the single case.

SIMULATION OF ACCIDENT INITIATION SEQUENCES

To simulate the accident initiation sequences some information are necessary. In the following chapters the real as well as the virtual simulation of accident initiations will be explained.

Information from accident site

The method uses detailed informations out of the accident sketch, which is available for all accidents in GIDAS. Figure 5 show an example of such an accident sketch.

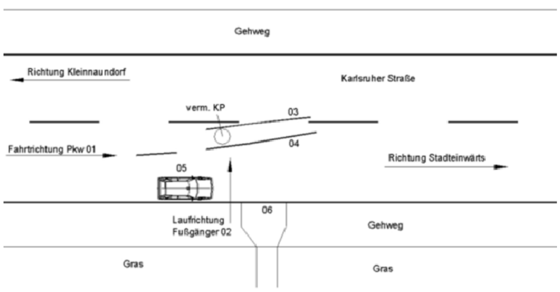

Figure 5 - Detailed accident sketch

Not all information of these accident sketches are important for the simulation process. Therefore only the necessary information as shown in Figure 6 are derived from the accident sketch.

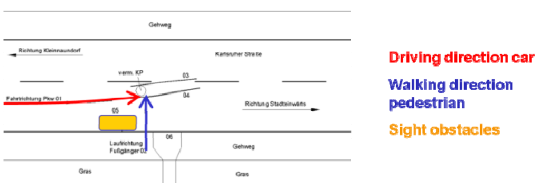

Figure 6 - Derived information from accident sketch

Additionally to these mainly static data of the accident site, the movement of all participants are necessary. These information are included in the accident reconstruction records of GIDAS. The initial movement as well as all sequences up to the first impact, the impact parameter and all post impact movements are recorded in detail in several records. This information is used to reconstruct and simulate the real accident initiation.

Figure 7 shows initial situation of the reconstruction.

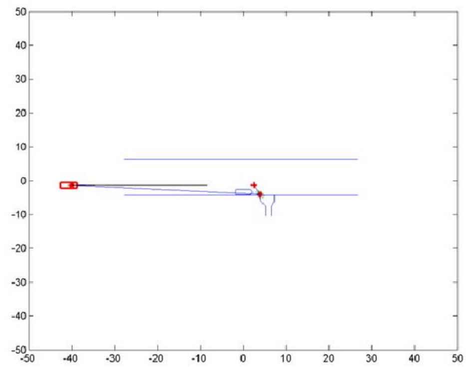

Figure 7 – Initial situation of reconstruction

Simulation of the real accident initiation

Subsequent to the reconstruction of the accident, the complete initiation phase will be simulated using a dynamic computer simulation environment MATLAB, Carmaker or the like. In Figure 8 the result of such a computer simulation is shown.

Figure 8 - Simulation of the real accident initiation (side view)

As shown in Figure 9 it is possible to vary the perspective on every static or dynamic point in the scenario.

Figure 9 - Simulation of the real accident initiation (drivers view)

Parallel to the simulation it is possible to analyse different parameters chronologically. In Figure 10 the chronological visibility of the pedestrian due to view obstacle "parked car" is shown.

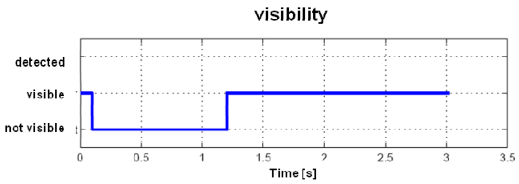

Figure 10 - Visibility of the pedestrian in the real accident initiation

The consideration of view obstacles is very important, cause of the known high influence in car to pedestrian accidents.

In addition to that the deceleration and consequent to that the driven speed are shown in Figure 11 and Figure 12.

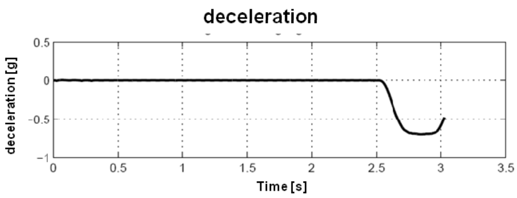

Figure 11 - Deceleration of the car in the real accident initiation

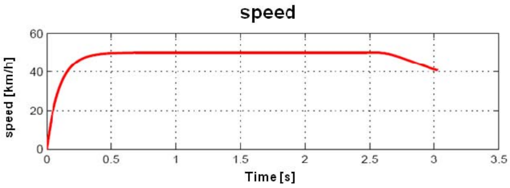

Figure 12 - Speed of the car in the real accident initiation

With this detailed simualtion of the real accident scenario it is possible to get a better understanding of the single accident and to define possible avoidance strategies.

Definition of the forward looking safety system

To simulate a virtual accident initiation with the influence of a safety system, the system operating mode has to be defined previously. The more accurate the system is described, the better and the more robust results could be estimated.

Especially the following parameters, exemplary for a forward-looking sensor based safety system, have a high influence of the system benefit itself:

- Triggering algorithms
- Sensor characteristics
- Sensor position at car

The triggering algorithm is responsible for an early detection of the pedestrian and has therefore a direct influence on the benefit of the system. Nevertheless the system has to be considering that the rate of false positive is as low as possible.

The sensor characteristic itself describes the sensor range and angle. These parameters have also a direct influence on an early detection of the pedestrian. At last, the position of the sensor in the car (e.g. on the front or at the windscreen) has an influence on the detection of the pedestrian and therefore a direct influence on the system benefit.

In Figure 13 the definition of a forward-looking sensor based safety system is shown.

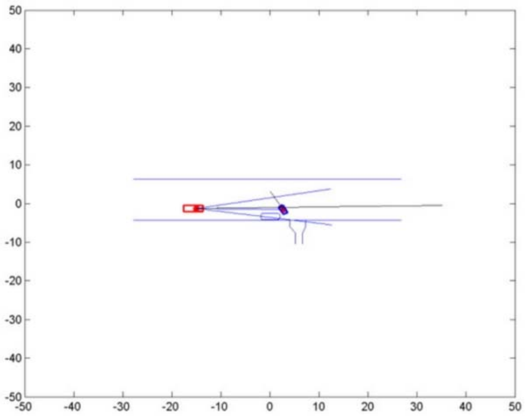

Figure 13 - Definition of the forward-looking safety system

With the detailed definition of the forward-looking safety system it is now possible to simulate the accident initiation again.

Simulation of the virtual accident initiation with system

The simulation of the virtual accident initiation with safety system starts at the same initial situation as in the real accident situation.

Additionally the complete system operating mode was implemented in the car. Therewith the system interacts with the accident initiation situation and could reduce for instance the speed automatically if the pedestrian was detected.

In Figure 14 and Figure 15 the virtual accident initiation for the example case is shown.

Figure 14 - Simulation of the virtual accident initiation (side view)

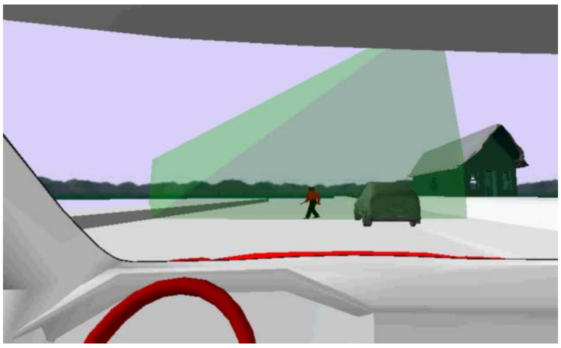

Figure 15 - Simulation of the virtual accident initiation (drivers view)

In Figure 16 the visibility and the detection of the pedestrian is shown in a chronological order prior to the crash.

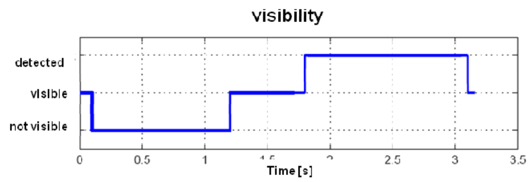

Figure 16 - Visibility of the pedestrian in the virtual accident initiation

It could be seen, that nearly half a second after the pedestrian was visible (not behind a view obstacle), the system could detect the pedestrian.

In Figure 17 - System triggering in the virtual accident initiationFigure 17 the system activation is shown. This activation mainly considers to the system triggering algorithm.

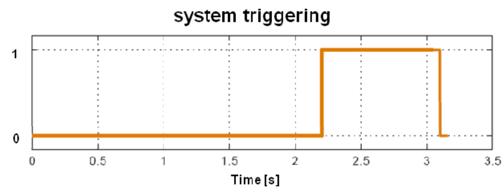

Figure 17 - System triggering in the virtual accident initiation

The system activation leads to an autonomous emergency braking of the car. This results in a deceleration as shown in the Figure 18.

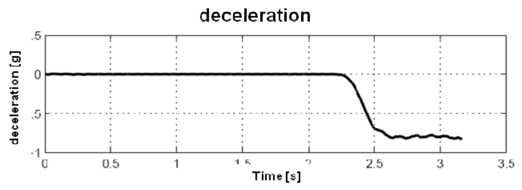

Figure 18 - Deceleration of the car in the virtual accident initiation

In Figure 19 the corresponding speed curve is shown.

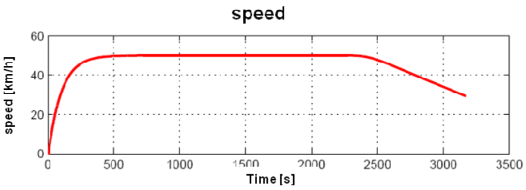

Figure 19 - Speed of the car in the virtual accident initiation

In comparison to the real accident situation it could be seen, that the collision speed in the virtual crash scenario is reduced from nearly 40 km/h (see Figure 12) to less than 30km/h due to the activation of the forward-looking safety system and the autonomous emergency braking. The effect is limited due to the fact that the driver has also reacted in the real crash. (see Figure 11)

The reduced collision is now used to calculate the expected benefit in mitigation of injury severity. Therefore the injury risk function as shown Figure 20 was used.

Figure 20- injury risk function for car to pedestrian impacts

This described procedure for the single accident was further done for all car to pedestrian accident in GIDAS. With this method it is possible to estimate the overall real world benefit of this forward-looking safety system.

This overall benefit only depends on the system operating mode and the detailed defined and described triggering algorithm, sensor characteristics and position at the car.

Due to those very specific properties of the single system, the results could not be generalized to other comparable forward-looking safety systems.

CORRELATION BETWEEN TESTRESULTS AND REAL WORLD BENEFIT

To compare the system effectiveness between different forward looking safety systems a lot of test procedures were developed in the past. But the developed test procedures could only verify limited number of scenarios. Additionally that it could be only assumed that the test results of the scenario are correlating with the real world benefit of the system.

Test scenario for forward-looking safety systems

In Figure 21 a typical test scenario for forward-looking safety systems is shown. The car often has an initial speed of about 40 km/h and the walking speed of the pedestrian is mostly near to 5 km/h.

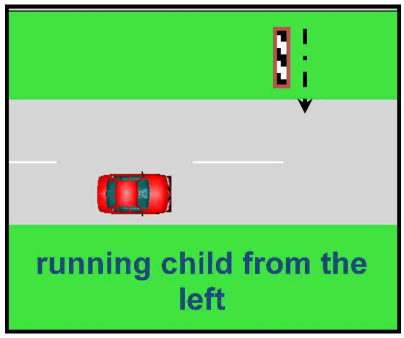

Figure 21 – Test scenario for forward-looking safety systems

Each system could be tested with this scenario. But depending on the system specification and operating mode, every system will have a specific test result.

Correlation to real world benefit

In Figure 22 a specific real world benefit in correlation to the result of this system in the test scenario is shown.

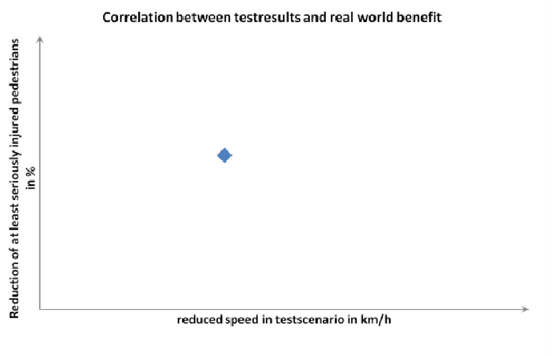

Figure 22 - Correlation between testresults and real world benefit (single system)

In a further step in this study correlation between comparable system configurations and the expected real world benefit regarding to the result of the test were developed.

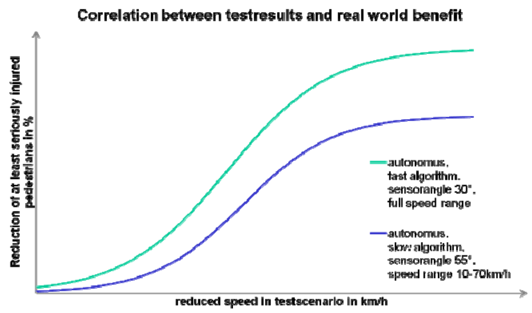

Figure 23 - Correlation between testresults and real world benefit (system groups)

Like shown in Figure 23 it is possible, to correlate the result of the test scenario of a specific forward looking safety system to the real world benefit of this system.

Therewith it is possible to assess the benefit of forward-looking safety systems much more in detail. Especially properties of the system like system operating mode in darkness or speed ranges which do not have an effect in the testscenario could be considered due to the real world benefit of the system

This method is suitable to any test procedure so that rating methods could consider these system properties too. It is therefore qualified to include these system properties, which could not be directly tested. The test effort could be reduced and simultaneous the benefit of non testable properties could be implemented in the rating procedure.

SUMMARY

The complexity of forward-looking safety systems will further increase in the future. Not all system specifications and properties could be tested with fungible expence. The paper describes a method to simulate all system specifications in detail using case by case simulations.

In addition to that system groups with comparable specifications could be assessed regarding the real world benefit. The correlation to different test scenarios and results gives the possibilities to include these properties into the real world benefit estimation.

Therewith the test effort could be reduced significantly and the accuracy of the benefit assessment could be further optimized.