Creation of pre-crash simulations in global traffic accident scenarios based on the iGLAD database

Dipl.-Ing. F. Spitzhüttl*. Dipl.-Ing. H. Liers*
Dipl.-Ing. (FH) M. Petzold*

**Traffic Accident Research Institute at University of Technology Dresden, Dresden, Germany (Tel: +49 351 438989 0; e-mail: florian.spitzhuettl@vufo.de).*

Abstract: Due to the globalized development of vehicles and advanced driver assistance systems (ADAS) in combination with the large variety of traffic situations all over the world, there is an increasing need of evaluating the effectiveness of ADAS on the basis of international real traffic data. This can be done with the help of so-called pre-crash matrices (PCM), which describe the vehicle dynamics in a defined time before the collision. After the publication of the first IGLAD data (1.550 accidents) a study was done dealing with the creation of pre-crash simulations out of international accidents. For the first time the benefit of an ADAS can be evaluated prospectively in the wide variety of global traffic accident scenario. This paper provides an overview of the challenges that come with merging data from different investigation areas. The main focus will be on the methodology to derive PCM from this international database. This also includes the definition of minimum requirements to enable the simulation of the vehicle behavior in the pre-crash phase. Furthermore, methods were developed how to deal with unknown data with regard to the different data quality and quantity. Finally the paper shows the unique possibility to analyze active safety systems from a global point of view by implementing and assessing an exemplary ADAS for different global traffic accident scenarios.

With the work done within the study, especially with the definition of minimum requirements and the developed methods, it is possible to create pre-crash simulations not only for upcoming iGLAD releases but also for other international accident databases.

Keywords: *accident scenario, road traffic, vehicle dynamics, advanced driver assistance systems, active safety, global traffic scenario, pre-crash phase, in-depth accident data.*

1. INTRODUCTION

For the development of advanced driver assistance systems (ADAS) information of the pre-crash phase are required. Therefore so-called pre-crash-matrices (PCM) can be used, as shown in (C. Erbsmehl et al., 2012). They describe the motion of participants of the accident just before collision. Additionally, current or future ADAS can be implemented in the pre-crash phase and thus an evaluation of their efficiency, as described in (Dr. H. Schittenhelm et al., 2008), is possible.

Applying that methodology to the data of the German In-Depth Accident Study (GIDAS) already produced significant results, but only for German traffic accident scenario. However, international traffic scenario is also important for the development of vehicles and their ADAS. After the first publication of the “Initiative for the Global Harmonization of Accident Data” (iGLAD), see (Bakker, 2012), it would be possible to prospectively analyze the safety potential of ADAS within the variety of road traffic accidents from around the world for the first time. Due to a smaller data volume of the iGLAD database compared with the GIDAS database, missing data is expected and the formulation of minimum requirements and the development of compensation methods seem to be necessary.

In the framework of this study a methodology for the creation of pre-crash simulations out of international accident databases is developed. The depth of information of the iGLAD data (phase I – 1.550 accidents) shall be determined and a PCM shall be created. The efficiency of an exemplarily ADAS in the field of global accident scenarios will be simulated and analyzed.

2. INITIATIVE FOR THE GLOBAL HARMONIZATION OF ACCIDENT DATA (iGLAD)

The motivation for founding an initiative like iGLAD is that traffic safety becomes more and more important from a global point of view. While fatalities due to traffic accidents are slightly decreasing in high-income countries they are strongly increasing in middle-income and low-income countries, see figure 1. Even with pessimistic predictions the worldwide number of traffic fatalities will increase tremendously in the next decade(s). The publication of the World Health Organization (WHO) “World report on road traffic injury prevention” of 2004 estimated the annual number of fatalities up to 1.3 million and around 20-50 million injured people (World Health Organization, 2004). Eighty-eight countries have reduced the number of deaths on their roads, but the total number of road traffic deaths remains unacceptably high at 1.24 million per year (World Health Organization, 2013).

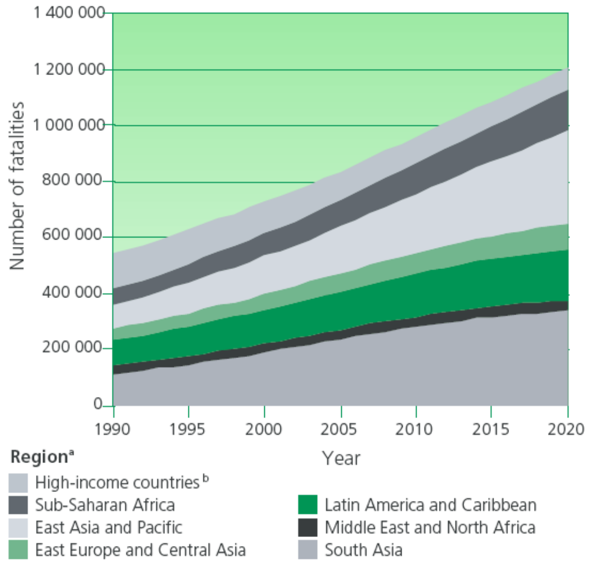


Fig. 1. Road traffic fatalities, 1990–2020 (World Health Organization, 2004)

Current trends suggest that by 2030 road traffic deaths will become the fifth leading cause of death unless urgent action is taken (World Health Organization, 2008). Therefore the need for action in this field and by association for an international in-depth database and its further improvement process is still very high or even increasing.

Therefore the "Initiative for the Global Harmonization of Accident Data" (iGLAD) was launched in 2011 as a collaborative project of the European Automobile Manufacturers Association (ACEA) and the Fédération Internationale de l'Automobile (FIA). Currently ten traffic accident research institutes from Europe, North America, Australia and Asia take part in the project (see figure 2).

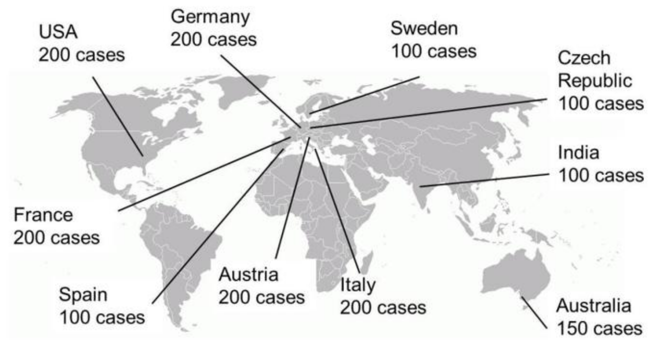


Fig. 2. Data providers of iGLAD phase I *("Data description, Data providers 2007-2012 data," 2014)*

The aim is to merge high-quality data from different national in-depth investigations. The big challenge of a harmonized accident database is the different data content of the single in-depth investigation projects. So on the one hand side it is important to ensure a minimal quality standard, but on the other hand side it is necessary to enable a useful comparison and evaluation of the efficiency of ADAS on several markets (Ockel et al., 2011). The iGLAD project members currently finished phase I. The database of phase I contains 1550 cases from 10 countries, like shown in figure 2. The inquiry period was 2007 to 2012 and each case includes information on 75 variables regarding accident, road, participants (information about vehicles and pedestrians), occupants and safety systems. Coming phases are in progress.

3. PRE-CRASH SIMULATION

ADAS are systems which assist the driver in the driving process to improve vehicle safety. Most of them have substantially reduced or will reduce the number of seriously and fatally injured persons. Therefore further development and improvement is important to support this progress. To prospectively determine the effect of an ADAS it is possible to estimate the benefit by contrasting the original scenario (no ADAS implemented) with the virtual situation with an implemented system and to compare significant parameters (see figure 3). Benefit estimations based on actual (crash) tests are limited due to small number of test scenarios and very high costs. Contrary to that simulations of accident scenarios give the possibility to estimate the benefit in a nearly infinite variety of scenarios representative for the real traffic accident scenario. Therefore, the actual vehicle behaviour in real traffic accidents has to be simulated and information about the pre-crash-phase is needed necessarily.

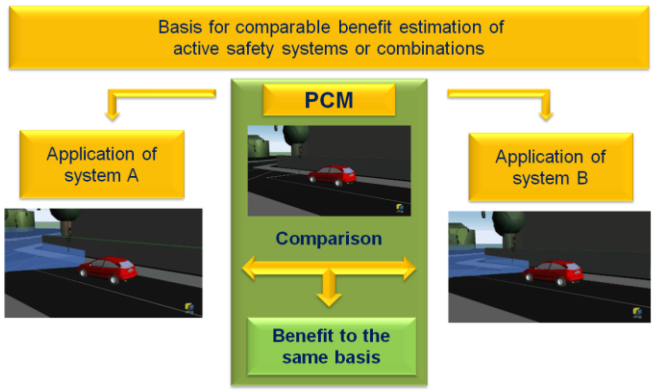


Fig. 3. Comparable benefit estimation of active safety systems

In-depth accident databases mostly contain much information about the in-crash and post-crash phases. Based on reconstruction of accident's chronological sequence it is possible to simulate the pre-crash-phase and to create so called Pre-Crash-Matrices (PCM). PCM contains information about vehicle dynamics of all participants for discrete time steps in a defined time before crash. Additionally information about surroundings, view obstacles and road markings can be contained. This data source can be used then to virtually implement ADAS into one or a large number of accident scenarios and to simulate the influence on driver and/or vehicle behavior. Afterwards, the simulation results can be used for further analyses, e.g. for benefit estimations using Injury Risk Functions (IRF).

Pre-crash simulation and evaluation of the efficiency of several ADAS based on the German In-Depth Accident Study (GIDAS) have already been established and produce significant results, but only for German traffic accident scenario. The challenge is to adapt its methodology to the iGLAD database.

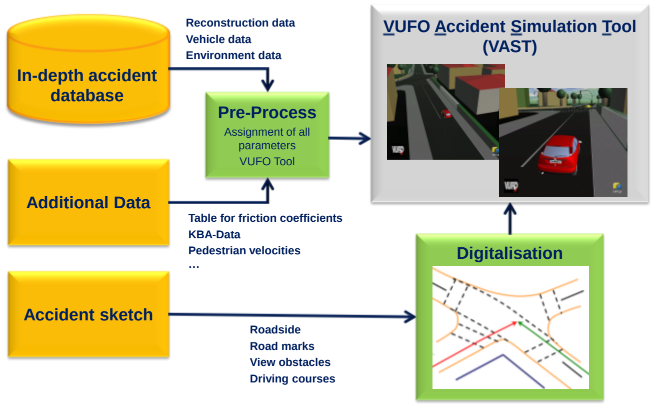


Fig. 4. Methodology of pre-crash simulation

4. PRE-CRASH MATRICES (PCM) FROM IGLAD DATABASE

4.1 Minimum requirements

The depth of information in the iGLAD database is not as high as in other real-world accident databases. For example the iGLAD database contains 71 variables within four tables, whereas the GIDAS database contains around 2,600 variables within 31 tables. This is no statement about the quality of included information but gives an indication that within iGLAD not all necessary information is available. It is expected that compensation methods as well as assumptions may be necessary. So minimum requirements are defined, characterizing necessary information which at least have to be available to enable pre-crash simulations.

The global data give some general information of the accident like the number of involved participants, combination of collision (meaning the part types of participants), number of collisions, collision type, accident type and some more.

The participant data contains all relevant information to parameterize the vehicles. Beside the numbers of the participants, which had the first collision of the accident, their geometry and further attributes of the participants are stored.

The dynamics data should give the motion characteristics of each participant. It contains global position, velocity, acceleration and global yaw angle of the vehicles. Furthermore the steering angle of the left and right front wheel should be specified. Another necessary information is, at which point the brake is actuated by the driver, so the point of reaction is specified.

The surroundings/environments data contains all the information about the surroundings like view obstacles, road geometry or marks. Roadside defines the relevant boundaries of the road, view obstacles describe relevant line-of-sight obstructions and marks define the relevant continuous, long interrupted and short interrupted road markings.

4.2 Analyses of the iGLAD database

According to the minimum requirements analyzing the released iGLAD phase I database is useful. Most of necessary global data is available for the majority of iGLAD phase I cases. The analysis shows that most vehicle data are not included in the iGLAD phase I data, see table 1.

Table 1. Analyses of participant data

Necessary data	iGLAD variable	Available [Qty.] ✔	Not available ✘	Alternative source
Participant number	PARTNR	2,881	0.0 %	-
Type of Participant	PARTTYPE	2,820	2,1 %	-
Vehicle dimensions	✘	✘	✘	VEHMAKE + MODEL + REGYEAR External car databases Approximation formula
Center of gravity	✘	✘	✘	
Inertia tensor I (Ixx, Iyy, Izz)	✘	✘	✘	
Track width	✘	✘	✘	
Wheelbase	✘	✘	✘	
Weight of vehicle	VEHMASS	2,414	6.5 %	
Vehicle engine power	POWER	2,267	21.3 %	
Coefficient of friction	✘	✘	✘	ROADCOND, WEATHER + Reconstruction

Only the type of participant, weight of vehicle and vehicle engine power are included but also not available for all cases. Therefore, all information for the parameterization of the vehicle dimensions, center of gravity, inertia tensor and so on have to be compensated or approximated. Most efficient method seems to be the use of the type of the participant, the vehicle make, the vehicle model and the year of first registration in combination with external car database. The big issue for an automated research is the variable for vehicle model which is saved as text in string format. Another challenge are different car markets, because there is no suitable global car database available. As a consequence the definition of default models seem to be necessary.

Dynamics data generally exist as parameters, but only available for around two third of all cases. Further information about global yaw angle and steering angles are not available. The global position of the vehicle has to be determined from the digitalized sketch. For motion characteristics available data does not automatically mean correct data. Therefore the data is checked to its plausibility regarding the iGLAD definitions of an uniformly accelerated (/decelerated) motion, see (1).

$$\vec{a} = \frac{d\vec{v}(t)}{dt} = \frac{d^2\vec{s}(t)}{dt^2} \qquad (1)$$

where $\vec{a}$ is the mean deceleration/acceleration (m/s2), $\vec{v}$ is the velocity (m/s), $\vec{s}$ is the distance (m) and t is the time (s).

Figure 5 shows the completeness and plausibility of the available dynamics data within the iGLAD database. It can be seen that completeness and plausibility is strongly varying across the data providers. It can be seen, that compensation methods are necessarily needed for dynamics data of the participants.

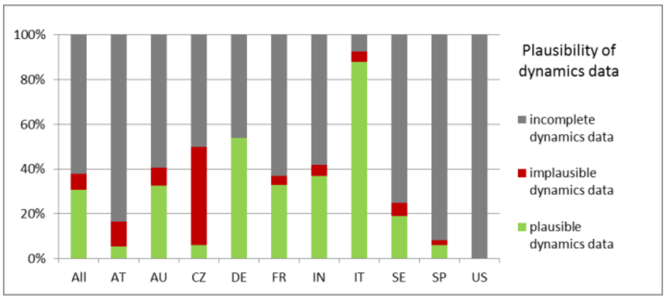


Fig. 5. Plausibility of dynamics data

The surroundings/environments data is mainly contained within the sketches. Therefore, the content of the provided sketches was analyzed. Table II shows the analysis of the minimum requirements for surroundings/environments, but only for potential cases regarding criteria named above (global data, participant data and dynamics data). It can be seen, that sketch content and quality varies strongly.

Table 2. Content of potential sketches

Country	No. of pot. cases	Trajectory	Impact pos.	Contact point	Final pos.	Road side	Scale	Pot. sketches
AT	16	9	6	1	9	10	10	0
AU	28	28	28	28	28	28	28	28
CZ	0	0	0	0	0	0	0	0
DE	59	56	52	47	54	59	59	43
FR	44	15	22	18	18	36	33	10
IN	0	0	0	0	0	0	0	0
IT	141	55	111	100	112	118	80	35
SE	4	1	1	1	1	4	1	1
SP	0	0	0	0	0	0	0	0
US	0	0	0	0	0	0	0	0
SUM	292	164	220	195	214	255	211	117

All these points clarifies compensation methods are absolutely essential to enable pre-crash simulation of global accident scenario. Without such methods there are just 117 cases (meaning less than 10 % of the whole iGLAD database) from mainly three data providers available for simulation.

4.3 Development of compensation methods

Due to non-fulfilment of the minimum requirements of the majority of the iGLAD cases, a defined dealing with missing data and the development of compensation methods are necessary to enable pre-crash simulations.

As already stated global data is existent for a high number of iGLAD cases. So generalized compensation methods are not necessary for such data. For missing information a single-case analysis is sufficient, if needed.

In contrast participant data has a lack of information within the database, so alternative data sources have to be found. It turned out that an appropriate method is the definition of standardized vehicle models which only depend on the type of participant. By this method the accuracy of the vehicle model decreases, but makes data available for a high number of cases. For passenger cars three example types have been defined for this study (mini model, compact model and maxi model). For further improvements vehicle body dependent models and also market specific models would be conceivable. This could improve the accuracy of the simulation.

The coded dynamics data within iGLAD and many other accident databases orientate on an uniformly accelerated (/decelerated) motion, see equation (1). Regarding to that, four values are defined as follows:

- the initial speed $\Rightarrow \vec{v}_0 = \vec{v}(t = 0)$
- the collision speed $\Rightarrow \vec{v}_k = \vec{v}(t = t_k)$
- the mean deceleration $\Rightarrow \vec{a}(t)(= \text{const.})$
- the deceleration distance $\Rightarrow \vec{s}_k = \vec{s}(t = t_k)$

This means that one missing value is possible to be calculated by three known values without losing accuracy. But for all cases with more missing information it cannot be handled like this. So the next step is to make assumptions and to define default driver and vehicle behaviour. Useful assumptions are:

1) No deceleration/acceleration

$$\Rightarrow \vec{v}_0 = \vec{v}_k = \text{const.}$$

2) Full braking

$$\Rightarrow a = f(\text{road condition})$$

3) Default velocity

$$\Rightarrow \vec{v}_0 = f(\text{road type})$$

"1) No deceleration/acceleration" means, that there might be no reaction of the driver and the initial speed equals the collision speed. If there is no information about any deceleration or drivers reaction this is an easy assumption to compensation this missing information. Nevertheless it is clear that this decreases the accuracy of the real motion heavily. "2) Full braking" means that an emergency braking of the driver is assumed defining the deceleration as a function of the road condition, which gives a hint for the maximum coefficient of friction. "3) Default velocity" will just be used when nearly no information about the dynamics data is existing. In these cases a default initial speed as function of the type of road and the existing speed limit will be assumed. This assumption would be the worst case and the simulated vehicle behaviour might be far away from real vehicle motion characteristics.

Missing surroundings/environments data can only be compensated by single case analyses and high effort of redrawing the sketches with the help of all other database information including the accident description, global data, participants data, dynamics data and other information. If there is not enough information available at all, it is not useful to simulate such a low case quality anymore.

The more compensation methods and assumptions have to be used, the less accurate is the simulation of a case and both accuracy and reliability are not assessable anymore. The pre-crash simulation equals more generalized scenarios than the real traffic accident. On the other hand side with such methods about 600 further cases, meaning more than 35 % of the whole iGLAD phase I database, could be used for pre-crash simulation. Finally, a sensible grade of using compensation methods has to be found.

4.4 Creation of pre-crash matrices

Building up on the previous results pre-crash simulations are performed methodically. For cases with non-fulfilment compensation methods and assumptions were applied. A look on the originally available data and the used compensation methods per case is taken. So the simulation quality can be assessed, to have an idea of the accuracy of the resulting pre-crash simulation per case.

Figures 6 to 9 visualize schematically the methodology to create pre-crash simulations for the iGLAD database divided to the dynamics data, participant's data, sketches, and the overview. Within them the different possibilities for processing can be seen. If the information is available you can use the "✔"-path. If the information is not available the "✘- path" has to be followed and an alternative source has to be used or at least the case cannot be simulated because of too much missing data. If all necessary information from dynamics, participant data and the sketch are available and complete (see figure 10), it is possible to create pre-crash simulation for this case.

The developed methodology cannot only be adapted to upcoming iGLAD releases but also to other international accident databases.

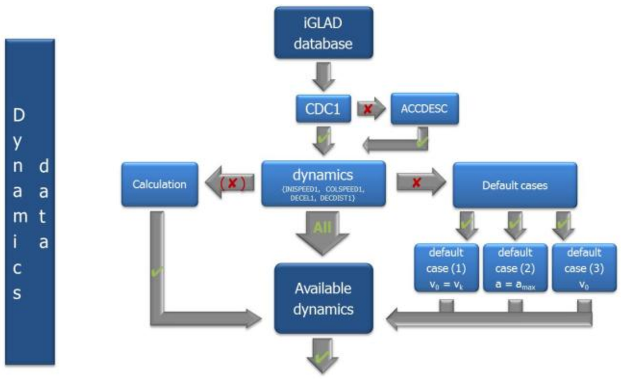


Fig. 6. Methodology of creating pre-crash simulations 1

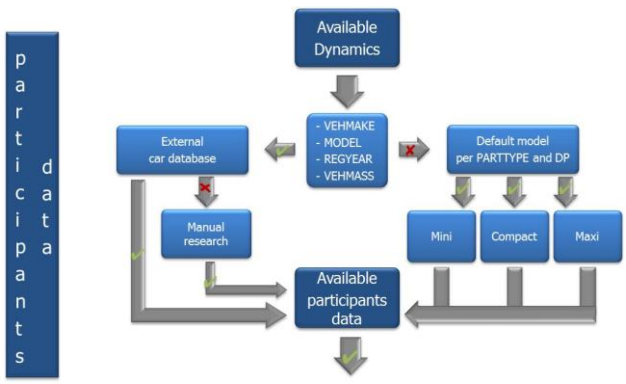


Fig. 7. Methodology of creating pre-crash simulations 2

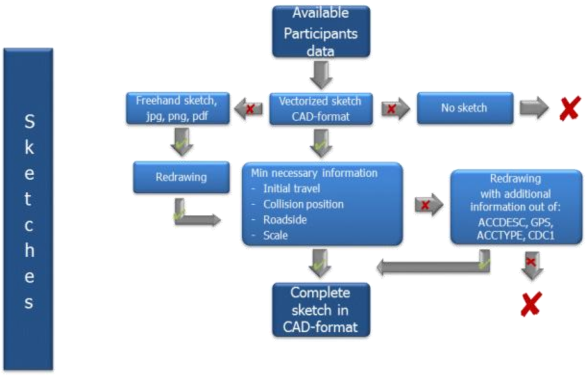


Fig. 8. Methodology of creating pre-crash simulations 3

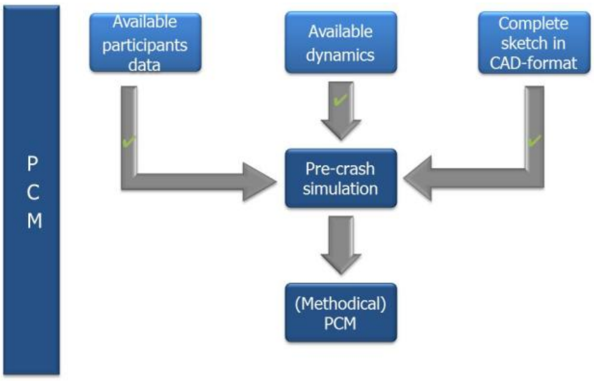


Fig. 9. Methodology of creating pre-crash simulations 4

Figure 10 shows the quality evaluation of the simulated cases, basing on the originally available data content and the used compensations methods and assumptions. Finally every simulated case has a quality number, which represents the lowest quality of the out of dynamics quality, sketch quality and simulation quality.

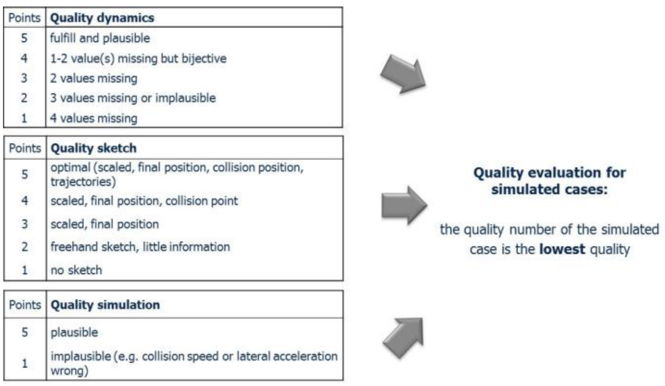


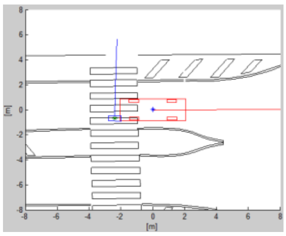
Fig. 10. Quality results of the Methodical PCM

4.5 Application of ADAS to pre-crash simulation

By using the created pre-crash simulations it is now possible to evaluate the effectiveness of an ADAS. Therefore two cases are representatively shown in this paper with and without an implemented Advanced Emergency Braking system (AEB). This demonstrates the benefit of pre-crash simulations from iGLAD database for the development of global road traffic safety. The implemented pedestrian-AEB system has the following characteristics:

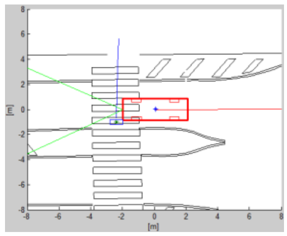
- sensor range: 50 m
- sensor opening angle: 60 °
- sampling rate: 0.1 sec
- triggering AEB @ TTC <= 1.2 sec
- minimum object width: 0.5 m

Figures 11 and 12 show the collision position of both participants of a passenger car – pedestrian accident (country of origin: Italy). The original collision speed was 31 kph. With the virtually implemented AEB system the speed was reduced to 24 kph. So the benefit in this example is a reduction of the collision speed of 7 kph. This information can be used as input parameter for an evaluation with the help of an injury risk function.



Collision speed: 31 kph

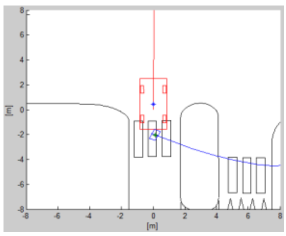
Fig. 11. Implemented ADAS – braking without AEB System



Collision speed: 24 kph

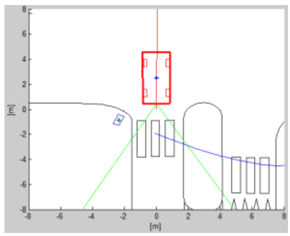
Fig. 12. Implemented ADAS – braking with AEB System

Figure 13 and 14 show the same implemented AEB for another passenger car – pedestrian accident (country of origin: France). In the original accident the passenger car collides with the pedestrian at a speed of 15 kph. With the implemented AEB system the collision could be avoided. So the benefit in this case is the complete prevention of the collision.



Collision speed: 15 kph

Fig. 13. Implemented ADAS – braking without AEB System



no collision

Fig. 14. Implemented ADAS – braking with AEB System

5. DISCUSSION

Pre-crash simulation and evaluation of the effectiveness of several ADAS based on the German In-Depth Accident Study (GIDAS) has already been established and produced significant results, but only for German traffic accident scenario. This study shows the possibility to do pre-crash simulation and furthermore evaluation of the effectiveness of ADAS by a reduced dataset of international data. The results exemplarily show the methodology for the iGLAD database and can also be adapted to other accident databases. For the first time it is now possible to prospectively analyze the safety potential of ADAS within the variety of road traffic accidents from around the world.

Due to a reduced dataset compensation methods and assumptions had to be introduced at the expense of accuracy and reliability of the results. The more data has to be compensated and the more assumptions have to be made, the more the results are brought closer to standard cases. To address this inaccuracy a quality criterion was introduced.

The representativeness of the iGLAD database was not analyzed within this study and thereby is unknown at this point. However, one main goal of the iGLAD project is to sample representative cases from every data provider to enable representative results in the future.

With the work done within the study, especially with the definition of minimum requirements and the developed compensation methods, it is possible to create pre-crash simulations not only for upcoming iGLAD releases but also for other international accident databases. Thus for the first time the safety potential of ADAS can be evaluated retrospectively and prospectively in the wide variety of global traffic accident scenario.

6. CONCLUSIONS

After the publication of the first iGLAD dataset a study was done dealing with the creation of pre-crash simulations out of international accidents. The main focus is on the methodology to create a Pre-Crash-Matrix (PCM) from this international database. This also includes the definition of minimum requirements to enable the simulation of vehicle behaviour in the pre-crash phase. Compensation methods were developed how to deal with unknown data with regard to the different data quality and quantity. Finally the paper shows the unique possibility to analyze active safety systems from a global point of view by implementing and assessing an exemplary ADAS for different global traffic accident scenarios. Thereby already existing ADAS and also systems which are in stage of development can be simulated and their expected benefit can be evaluated on global market.

Due to the increasing need of a high quality global in-depth database iGLAD is a continuously advancing project. Several groups (the technical working group, the steering committee, the data administration team) work together at further improvements. This means the database has no finished format and will improve with every period. Many improvements will result from this study, especially in terms of data quality, plausibility checks and requirements on sketches and reconstruction. The phase II will be finished within 2015, containing accidents from 2012 to 2013. Based on the results of this study some decisions were made by the iGLAD consortium to improve the data quality. Many of them are already included in the current phase II.

REFERENCES

Bakker, J., 2012. iGLAD - A pragmatic approach for an international accident database.

C. Erbsmehl, A. Schubert, Dr. L. Hannawald, M. Wagner, 2012. Nutzung des IPG CarMaker zur Simulation realer Verkehrsunfälle der GIDAS Datenbank, in: IPG Technology Conference. Presented at the apply & innovate 2012.

Data description, Data providers 2007-2012 data [WWW Document], 2014. . www.iglad.net. URL http://iglad.net/web/page.aspx?refid=2 (accessed 11.1.14).

Dr. H. Schittenhelm, J. Bakker, H. Bürkle, P. Frank, J. Scheerer, 2008. Methods for analyzing the efficiency of primary safety measures based on real life accident data, in: ESAR. Presented at the Expert Symposium on Accident Research.

Ockel, D., Bakker, J., Schöneburg, R., 2011. Internationale Harmonisierung von Unfalldaten; Fortschrittsbericht des FIA / ACEA Projekts iGLAD (Initiative for the Global Harmonization of AccidentData). VDI Kongress, Berlin.

World Health Organization, 2013. Global status report on road safety 2013: supporting a decade of action.

World Health Organization, 2008. The global burden of disease 2004 update. World Health Organization, Geneva, Switzerland.

World Health Organization, 2004. World report on road traffic injury prevention. World Health Organization, Geneva, Switzerland.