UR:BAN KA-WER: Accident Data Analysis and Pre-Crash Simulation for the Configuration and Assessment of Driver Assistance Systems in Urban Scenarios

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Abstract - The project UR:BAN "Cognitive assistance (KA)" aims at developing future assistance systems providing improved performance in complex city traffic. New state-of-the-art panoramic sensor technologies now allow comprehensive monitoring and evaluation of the vehicle environment. In order to improve protection of vulnerable road users such as pedestrians and cyclists, a particular objective of UR:BAN is the evaluation and prediction of their behaviour and actions. The objective of subproject "WER" is development support by providing quantitative estimates of traffic collisions at the very start and predict potential in terms of optimized accident avoidance and reduction of injury severity. For this purpose an integrated computer simulation toolkit is being devised based on real world accidents (GIDAS as well as video documented accidents), allowing the prediction of potential effectiveness and future benefit of assistance systems in this accident scenario. Subsequently, this toolkit may be used for optimizing the design of implemented assistance systems for improved effectiveness.

INTRODUCTION

BMWi-funded research project UR:BAN

Accidents in urban areas differ from the ones occurring on rural roads or freeways, their relative importance increasing with overall fatality numbers declining. This is due to the higher share of vulnerable road users involved in urban accidents (see fig. 1). Hazardous situations in urban areas pose particularly tough challenges for active driver assistance systems: Space confinement due to buildings close to roadsides and infrastructure elements, the relevant traffic situations are usually complex due to the high density of road users.

The objective of UR:BAN is to develop active driver assistance technologies for urban accident scenarios and the reduction of the number of injured road users in urban traffic. 31 partners including automobile and electronics manufacturers, suppliers, communication technology and software companies, as well as research institutes and cities have joined the cooperative project UR:BAN in order to develop advanced driver assistance and traffic management systems for cities. The focus is on human factors in all aspects of mobility and traffic. Research objectives are pursued in three main target areas: Cognitive Assistance (KA), Networked Traffic System (VV) and Human Factors in Traffic (MV).

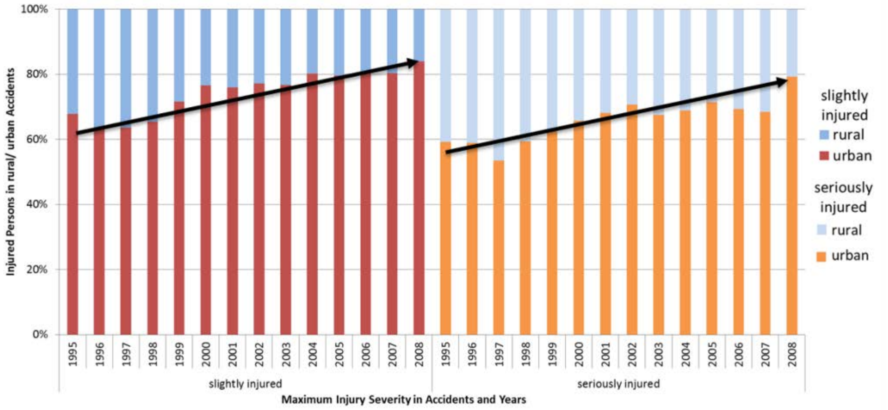


Figure 1: Trends in maximum injury severity in urban traffic accidents [GIDAS]

In UR:BAN KA, there are three subprojects addressing sensor requirements for the detection of various road user groups and assistance strategies. The project "Protection of Vulnerable Road Users (SVT)" further develops enhanced detection systems in order to avoid collisions involving pedestrians and cyclists. The project "Collision Avoidance by Swerving and Braking (KAB)" analyses optimized accident avoidance strategies for urban conflict situations such as accidents at intersections. In "Safe Lateral and Longitudinal Vehicle Control in Cities (SQL)", technologies designed for continuous support in longitudinal and lateral control e. g. on freeways are modified in order to facilitate acquisition and control tasks in demanding urban scenarios such as bottlenecks caused by parked cars as well. The cross-sectional subproject "Target Population, Effectiveness, and Law (WER)" supports the three application-based projects by assessment of accident avoidance potentials, effectiveness evaluation by virtual accident simulation and legal evaluation.

ACCIDENT DATA

GIDAS database

The major objective in assessing accident avoidance potentials is a precise assessment as to the positive potential of a driver assistance technology on accident scenarios in urban areas. This assessment requires accident data containing relevant accident parameters in order to determine the influence of functional limits (weather, road layout). Official police recorded accident statistics do not cover aspects such as collision speed or pre-crash trajectory, hence the accident data are limited and will not allow statistical traffic accident overviews. GIDAS (German In-Depth Accident Study) was established in 1999 as a cooperation project between the Federal Highway Research Institute Germany (BASt) and the research association on automotive engineering of German Car Industry (FAT). In-depth data in GIDAS combines data collection at the accident scene and the time of the accident applying retrospective methods like measuring, collection of medical data and accident reconstruction. The general concept of GIDAS is to compile a random, un-biased and representative sample of 2,000 accidents involving injury per year to cover all parameters of German road accident scenarios. No pre-selection of severe cases is performed, but all accidents involving injuries as defined by the police are considered. The accident reconstruction is conducted for each GIDAS case, a unique feature of GIDAS, since information for accidents of all severity classes [5] is available. The project UR:BAN focuses on the pre-crash matrices describing trajectories and kinematics of involved vehicles and pedestrians and therefore allow using reconstruction information of real accidents for the virtual simulation of driver assistance technologies during the development of these features.

KOTI data Video-recorded accidents

A further accident data source is a sample of 4,000 video documented accidents of Korean taxis in the region of Seoul [4]. Dash-board cameras are installed for legal reasons in taxis which record taxi driver trips and are triggered by events such as acceleration peaks. The data base covers all aspects of Korean urban traffic. These accident videos were analyzed to determine vehicle and opponent trajectories and link it with overall accident data such as type, site, weather and speed. Main advantages of this source are insights in real interactions, the pre-crash phase and triggering revealing whether or not e. g. pedestrians were aware of the approaching vehicle. This information is crucial for the development of active driver assistance technologies. The effectiveness assessment in UR:BAN can be amended by these insights, nevertheless at first differences between GIDAS data and KOTI data have to be determined.

Official German national accident statistics

BASt has access to the official German national accident data for scientific purposes allowing the analysis of all police reported accidents involving injuries in more detail than based on published accident statistics tables [6]. Full accident statistics ensure the linking of accident statistics with make and model of involved vehicles and analyze the effectiveness of safety devices. For UR:BAN, there are two applications for the use of national accident data: first, the number of accidents and involved injured persons of 2012 are used to extrapolate from GIDAS to the German accident numbers. Second, for SVT, these data may be compared to accident analyses with pedestrians and cyclists involved, since relevant scenarios are defined based on the 3-digit GDV accident type available in both GIDAS and 42 % of German national accident data.

ASSESSMENT METHODOLOGY IN UR:BAN KA-WER

Target population and effectiveness

The estimation of the target population and the evaluation of effectiveness are main tasks of the UR:BAN subproject Target Population, Effectiveness, Law. As shown in fig. 2, the effectiveness of a system is assessed in a two-stage process.

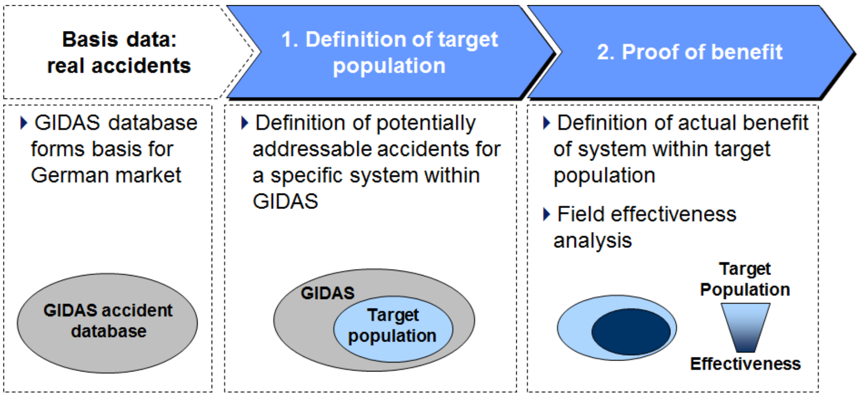


Figure 2: Two-stage process for verifying effectiveness

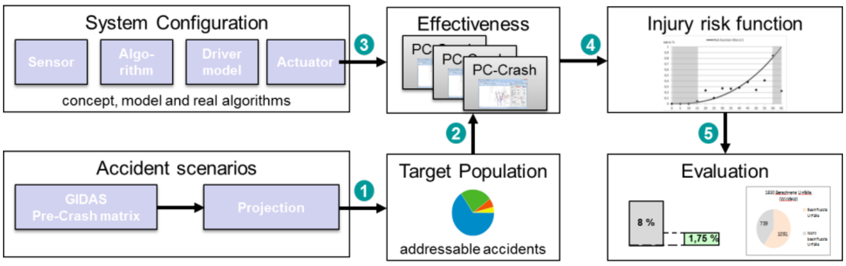
First, the target population of the system, i.e. all potentially addressable accidents need to be defined on the basis of the accident database. A precondition is detailed knowledge of these incidents. Not only the collisions themselves and their effects are crucial, but also in particular comprehensive information about the pre-crash phases, because active safety and driver assistance systems already engage during these periods. An optimal basis is a numerical description of the pre-crash phase based on accident reconstructions. The corresponding data for Germany are available in the GIDAS database (German In-Depth Accident Study, [3]) (compare paragraph ACCIDENT DATA)
The target population thus defined also sets the upper limit for the effectiveness of the system, corresponding to the effectiveness of optimized safety and driver assistance systems that could prevent accidents addressed by the systems. In reality, the benefit of a system will always be below this limit. The task of the software-based benefit assessment is to determine this percentage precisely. While the target population can still be determined via a selective database query, a temporally and geometrically exact simulation of the accidents is indispensable for determining the benefit of the system.

The goal of the virtual benefit assessment is to predict the effectiveness of safety and driver assistance systems for the overall incidence of German accidents, therefore, the data pool, which merely considers a subset of this total, must be projected. This step also considers a second aspect: Although GIDAS is approx. representative of traffic accidents in Germany (with the existing data acquisition scheme), deviations from the German Federal statistics [6] exist, which can be corrected by a method of extrapolation (compare paragraph PROJECTION).

The entire process of assessment within the subproject is illustrated in fig. 3. The starting point is the German accident situation, available from a representative random sample in the form of GIDAS PreCrash matrices (see [2]).

The next step defines, as described above, the target population of the system to be assessed. This also applies to selecting cases for the accidents to be simulated. The next step simulates the selected cases within the software. The accident reconstruction software PC-Crash forms the core of the simulation of the driving dynamics and the environment. The result of this simulation are modified technical collision parameters, such as Δv (change in speed due to the collision), the angle of collision and the point of contact for the individual accidents.

For converting the technical accident severity (represented by the result of the simulation in PC-Crash) into injury risks for the persons involved, injury risk functions are employed. These functions represent the risk of suffering an injury of the given severity as a function of technical parameters. For effectiveness assessment all persons involved in the particular accident are considered and each individual injury risk is evaluated. When all simulated accidents are taken into account the overall effectiveness of the system results. It is the reduced overall injury risk represented by vehicles with assistance systems is used to evaluate the effectiveness compared to the overall injury risk represented by cars without system.



1 Original accident scenario
2 Case selection
3 Driver Assistance system
4 Modified accident event (Δv, new collision angle)
5 Reduced injury severity

Figure 3: Effectiveness assessment in UR:BAN

DATA ANALYSIS (EXAMPLE)

In close cooperation with the application projects, the partners in WER developed and adjusted a “target population template” which allows filtering the overall urban accident scenarios by variables supposedly relevant to the sensor functions, algorithms or functional limitations. This harmonized template allows fast variation of the data analysis of more than 17,000 injured persons for the initial urban accident scenario in which a car was involved. By identifying accident conditions with a tick-box approach, relevant subsets based on combined characteristics can be extracted and compared in order to inform the developers on their system’s potentials.

These variables are either defining the overall conditions under which the accident occurred (weather, time of day, application area, trajectory) or vehicle-related data such as speed before the accident, driving maneuver or type of opponent (car, bicycle).

Some of the variables can be adopted directly from GIDAS, e. g. to analyze the data for weather conditions, since sensors could be influenced by snow or rain. Other variables are re-coded by using multiple GIDAS variables. E. g. the template variable “application area” describes the street type classified by aspects such as number of lanes, right of way and lane width. Fig. 4 shows an exemplary fictitious driver assistance system and how filtering leads to an addressed relevant subset of GIDAS cases. In this case, if the system is capable of addressing car-to-car lane change conflicts on straight roads with two lanes in one direction, a subpopulation of the urban accident remains as target population. The number of injured persons in relevant GIDAS cases is projected to national accident data by using the weighting factors (see paragraph PROJECTION)

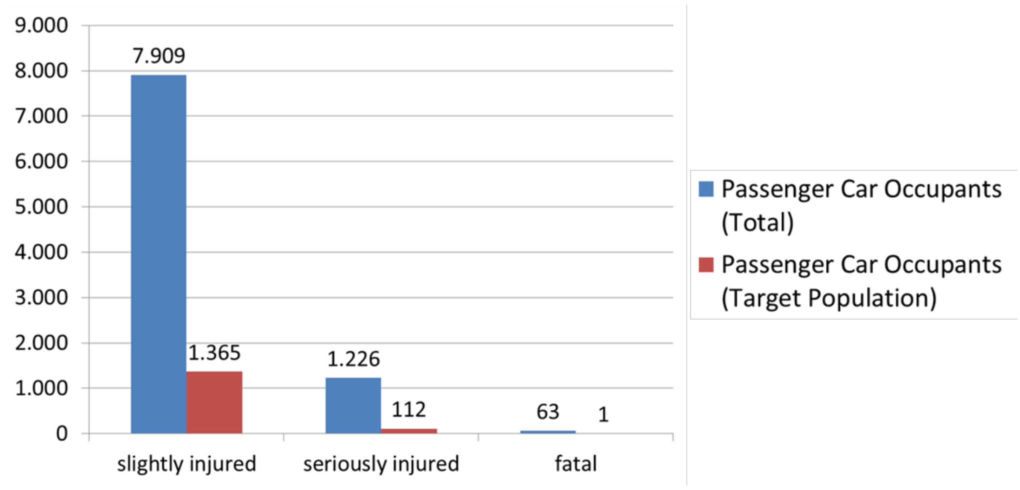


Figure 4: Example for target population analysis with WER template (own figure, GIDAS)

Another example for the WER contribution in UR:BAN is accident analysis focused on pedestrians and cyclists. The scope of the WER accident analysis conducted for SVT was to display relevant pedestrians and cyclists accident characteristics – and how they differ when accidents are aggregated to "SVT scenarios". In addition to the generic WER template, these scenarios were defined based on sensor and function capabilities with regard to pedestrian and cyclist detection, using the GDV accident type. F1 covered all accident type scenarios in which a pedestrian was crossing the street without obstruction, while F2 stands for the scenario "crossing with obstruction. F3 aggregated all turning in scenarios. Hence, all further variables were cross-tabulated by these scenarios (F1, F2, F3 and bicycle scenarios) in the analysis of all severely and fatally injured pedestrians and cyclists in GIDAS. Data in the national accident statistics allows replicating this approach, not with all depth, but a larger number of cases.

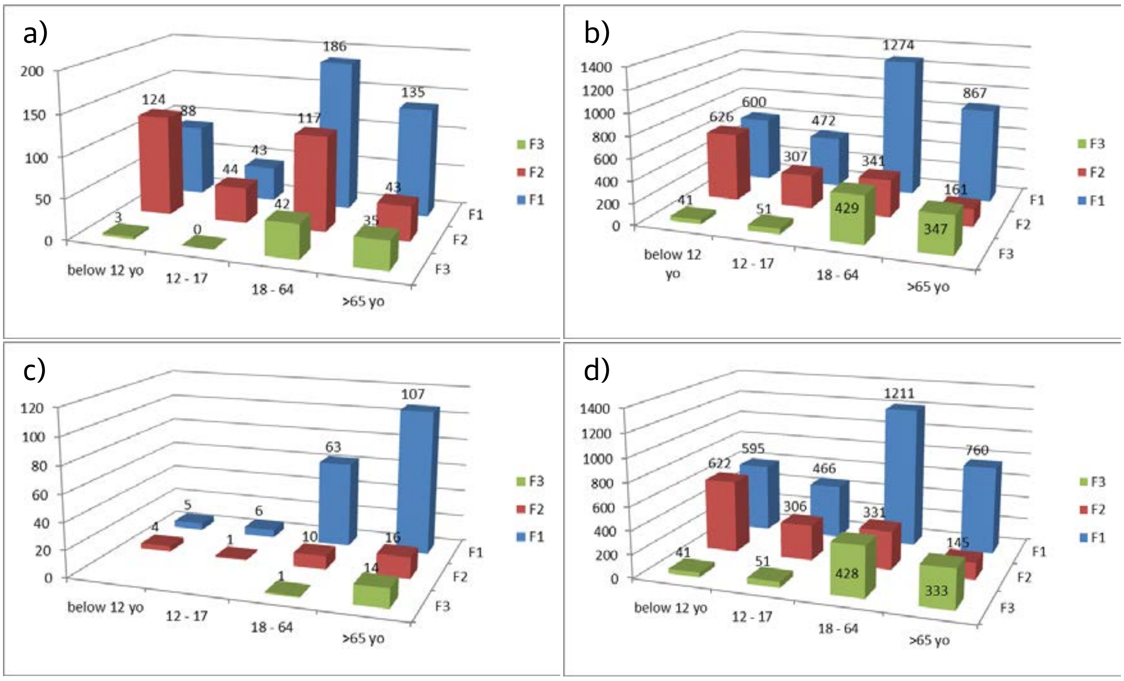


Figure 5: Pedestrians in SVT scenarios vs. age groups a) all severely and fatally injured in GIDAS b) all severely and fatally injured in DESTATIS (2008-2010) c) DESTATIS fatalities d) DESTATIS severely injured.

Fig. 5 shows that especially for insights on fatalities, this is a big advantage compared to GIDAS. Fig. 5 a) and 5 b) show a comparison of all severely and fatally injured in GIDAS (n = 860) by age group and scenario in comparison to all severely and fatally injured pedestrians in the national statistics sample (n = 5516). For the most important scenario F1, the age distribution matches well, for the obstruction scenario, children are more relevant in the larger sample. In 5 c) and 5 d), national accident data can be used to further distinguish severely from fatally injured pedestrians, which make it obvious that the elderly are at highest fatality risk across all scenarios.

In general, this analysis of a larger sample of accidents with vulnerable road users confirmed the conclusions drawn from GIDAS. The accident types 421 – pedestrian on straight road without obstruction from the right and 401 – the same scenario from the left – are the most important in both datasets.

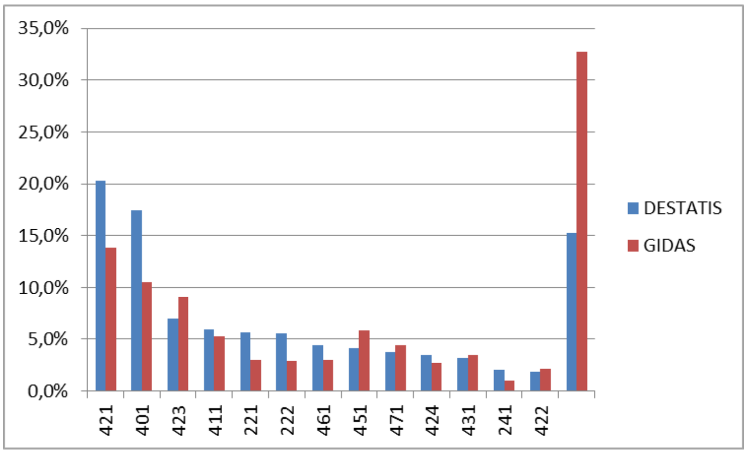


Figure 6: Comparison of relevant accident types (3- digit GDV) from GIDAS and DESTATIS sample

PROJECTION

GIDAS is approximately representative for the German accident scenario, since a random sample of all road traffic injury accidents is collected in two analysis sites. However, the number of cases collected each year and in total is small compared to the 300,000 accidents with at least one injured road user in Germany each year. Moreover, there are differences between the occurrence of accident constellations when comparing GIDAS with national statistics. Weighting the accidents within the GIDAS database, results from GIDAS can be both scaled up and corrected with an appropriate scaling-up method. In UR:BAN, the sub-project amended the two-stage approach used by Volkswagen which uses first accident distributions and corrects these figures by the real injury distributions in the second stage.

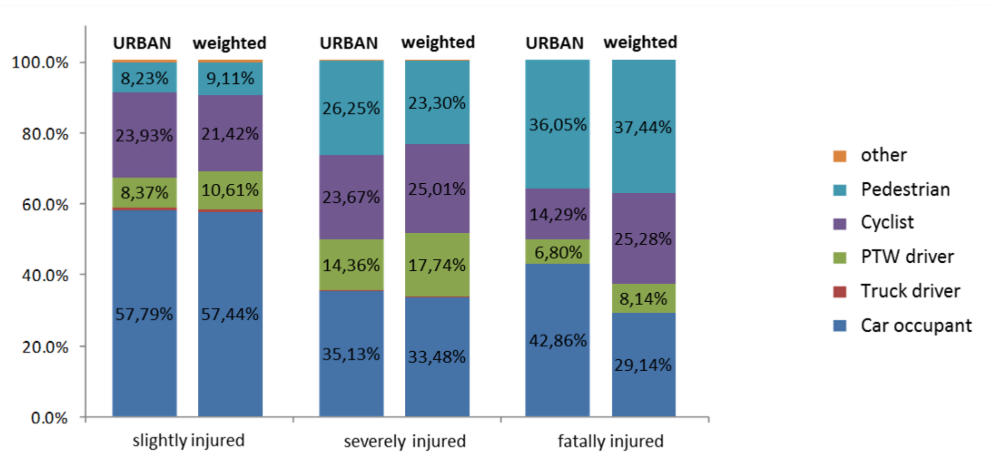


Figure 7: Urban accident where cars are involved: Injured road users in UR:BAN target population unweighted (left columns) and scaled up to German accident numbers 2012 (right columns).

Relevant variables that are matched to correct GIDAS to the national accident scenario of 2012 are kind of accident, location and accident severity, and on road user level, kind of participant and age for car occupants. Figure 7 shows, how this decreases the share of car occupants, but increases the relative importance of cyclists and powered two wheeler users.

The projection methodology uses correction factors that show a deviation supposedly meaningful for results to draw upon the GIDAS data, such as accident types (longitudinal, crossing, pedestrian) and road type. Hence, it is interesting to compare the projected figures with another significant accident statistics in the DESTATIS data – the number of injured road users by opponent type in urban accidents with at least one car involved [6, p. 103ff]. Figure 8 shows that for severely and fatally injured road users in the analysis of UR:BAN, the match shows a strong accordance of weighted GIDAS and the original figures.

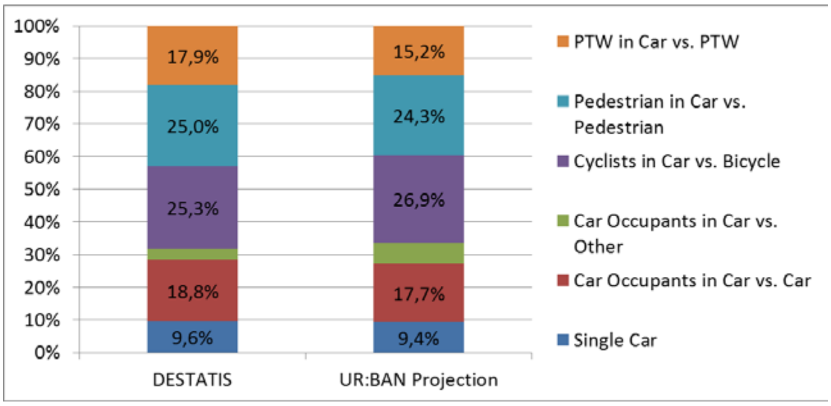


Figure 8: Comparison of weighted GIDAS data (UR:BAN target population) and DESTATIS data; fatally and severely injured road user in urban accidents with at least on car and with two participants maximum

SUMMARY AND DISCUSSION

Accident analysis may provide important impulses for the development of driver assistance systems. It is important to retrospectively analyze accident data by comparing target populations and determine the influence of system limitations on the one hand. On the other hand, prospective effectiveness evaluation may help discover further aspects of real accidents to consider in the development of these functions.
As a result, WER provides transparency and benefit from an evaluation of target populations and effectiveness of active driver assistance based on re-simulation of real-world accident data. Based on the accident analysis in UR:BAN, the applications developed in the UR:BAN project focus on the reduction of fatally and severely injured road users.

The WER subproject cooperates alongside the development process with the application projects in UR:BAN. Within the cooperation the target populations of UR:BAN driver assistance systems are iteratively optimized and various system performance parameters for the effectiveness simulation can be applied to find the best configuration of the system. The methodology makes use of the full information depth of GIDAS and projects findings based on GIDAS to German national accident figures.

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