Methods for analyzing the efficiency of primary safety measures based on real life accident data

Schittenhelm, Dr. Helmut, Bakker, Jörg, Bürkle, Heiko, Frank, Peter, Scheerer, Joachim
Daimler AG, D-71059 Sindelfingen, Germany

KEYWORDS – effectiveness of primary safety measure, collision avoidance, brake assist, advanced cruise control, rear-end crash, active safety, safety benefit, real world accident data

ABSTRACT

Primary safety measures are designed to help to avoid accidents or, if this is not possible, to stabilize respectively reduce the dynamics of the vehicle to such an extent that the secondary safety measures are able to act as good as possible. The efficiency of a primary safety measure is a criterion for the effectiveness, with which a system of primary safety succeeds in avoiding or mitigation the severity of accidents within its range of operation and in interaction with driver and vehicle. Based on Daimler´s philosophy of the “Real Life Safety” the reflection of the real world accidents in the systems range of operation is both starting point as well as benchmark for its optimization.

This paper deals with the methodology to perform assessments of statistical representative efficiency of primary safety measures. To be able to carry out an investigation concerning the efficiency of a primary safety measure in a transparent and comparable way basic definitions and systematics were introduced. Based on these definitions different systematic methods for estimating efficiency were discussed and related to each other. The paper is completed by presenting an example for estimating the efficiency of actual “single” and “multi” connected primary safety systems.

INTRODUCTION

For Mercedes-Benz, automotive safety is not just a question of fulfilling crash tests. Mercedes´s innovations in the area of primary and secondary safety have been based successfully on findings of accident research for 39 years. Reality still is and continues to be the benchmark of the development of effective primary and secondary safety measures. The development of modern safety measures is a holistic process (figure 1) which is based on accident research, basic research on driver behaviour (situation based human or operating error), development and integration of new sensor, perception and actuator technologies. During the development process ample simulation series [6], system tests at test areas [5] and driving simulator tests are used to design and optimize the assistance systems [3]. During the final step customer-orientated testing of the system is organized. However, after the system is introduced it takes several additional years for it to penetrate the market. Only then it is possible to gain information on its efficiency based on real world accident statistics. Many of these systems take more than a decade of years to achieve a sufficient penetration rate. This immense lag of time is not acceptable for the development of safety measures that had to be efficient on the base of reality like it is required by Mercedes-Benz.

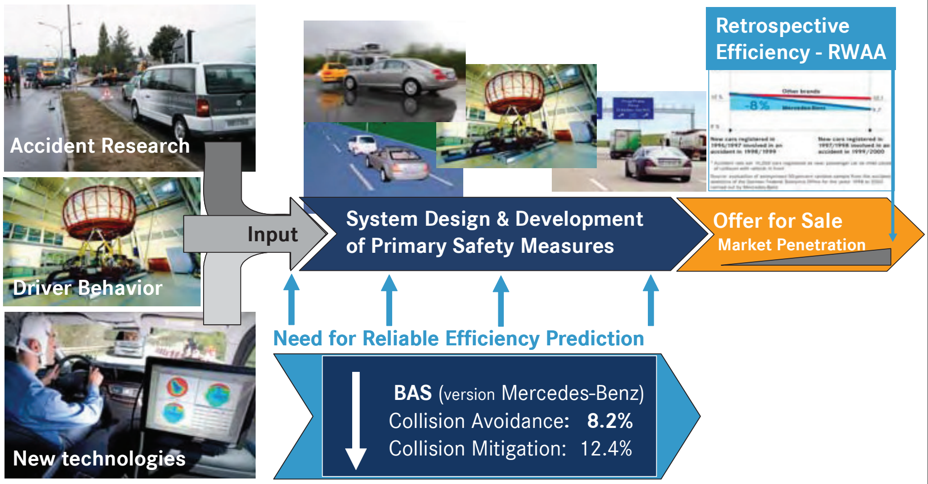

Figure 1: The need for statistically significant efficiency prediction during the development of safety measures and beyond

For the optimization of the development process described above it is essential to have statistically reliable predictions for the expected efficiency available continuously from the choice of a promising idea for the design of a new safety measure to the starting point of its development and through the whole process. So it becomes possible

- to focus on those primary safety measure that addresses most efficient relevant accidents and conflict situations resulting from human errors,
- to configure an efficient set of optimal balanced sensors, actuators and algorithms,
- to optimize the efficiency of the function by preliminary design using simulation methods,
- to obtain reliable information that the customer can expect from the system as benefit.

Efficiency analysis is the key technology to achieve such an improved development process.

DEFINITIONS

For analyzing the effect of primary safety measures it is useful to define terms that describe abstract characteristics of an accident or concrete accidents of a given characteristic e.g. in an existing data base. A characteristic could be e.g. a parameter that produces an accident like the conflict, an environmental parameter like ice or a property like skidding. Another useful distinguishing feature is that between the relative and the absolute effect. To be able to do so the definitions from [9, 20] were adopted.

The **area of conflict** [**AoC**] of a primary safety measure is defined as the pooling of abstract standardized conflict situations, in which the primary safety measure should be operating, avoiding or reducing accident severity due to its specifications. Use-cases which can be categorized as accidents are an example that makes up an "area of conflict". A(n) (representative) accident data base is the origin for the following explanations. It contains all kinds of accidents. Often it is useful to restrict the analysis to accidents which confirm to certain requirements – e.g. accidents with a certain severity.

The **area of reference** [**AoR**] is the set of cases that form the basis for the analysis. Depending on the type of question that has to be answered, a different set of accidents for the area of reference is selected, for example only fatal accidents or accidents with severely injured casualties.

The **area of action** [**AoA**] is defined as the mapping of the area of conflict in representative real life accident data contained in the data base respectively the **AoR**. It is the totality of accidents contained in **AoR** which correspond to the conflict situations in the area of conflict.

The **area of efficiency** [**AoE**] is defined as the subset of the area of action, in which the primary safety measure is able to avoid or mitigate the severity of accidents. For this subset of **AoA** the design specifications satisfy the physical parameters of the accidents.

The **degree of efficiency** [**DoE**] is defined as the quotient of the number of accidents in the area of efficiency and in the area of action.

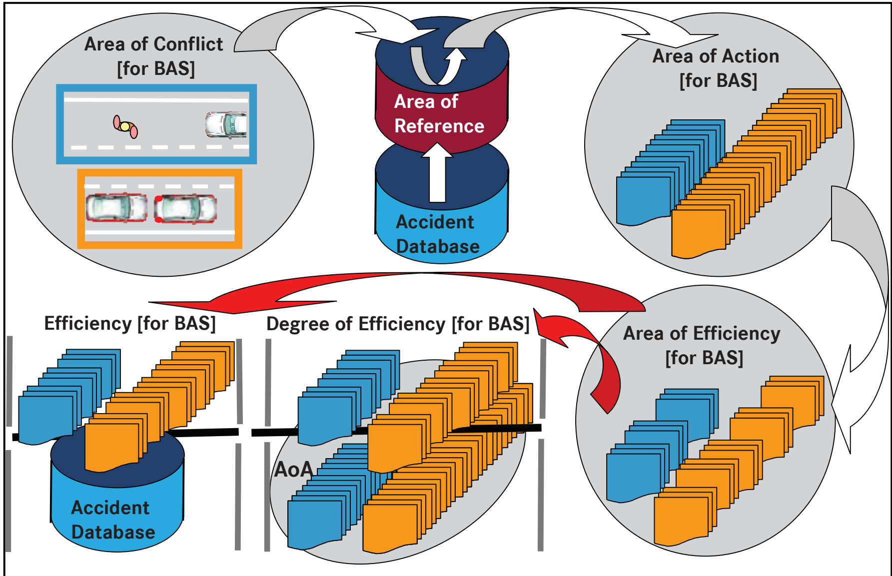

Figure 2: Visualization of the definitions around efficiency

The **efficiency** is defined as the quotient of the number of accidents in the area of efficiency and the number of accidents in the area of reference.
The **absolute efficiency** is given by the efficiency when AoR and AoA are equal to the accident data base.
The adjunct **"representative"** is used to clarify that the allocation accident data base was representative.

EXAMPLES

By definition **AoR** is a subset of the (representative) accident data base, **AoE** is a subset of **AoA** and **AoA** itself is a subset of **AoR**. An illustration of the terms defined above and their dependencies is shown in Figure 2 using the primary safety measure "Brake Assist (BAS)" as an example. Here the **AoC** consists of the accident types "collision with traffic moving ahead, waiting or starting", "collision with a pedestrian crossing the street".

For illustration we choose GIDAS for the accident data base in this example. For exemplification **AoR** is chosen to be the set of all accidents (and their documentation) in GIDAS with injury MAIS 3+ (seriously injured). **AoA** then is a subset of all accidents contained in GIDAS with injury MAIS 3+ which were of the kind "collision with traffic moving ahead, waiting or starting" or "collision with a pedestrian crossing the street". **AoE** is the subset of these cases where the brake assist (BAS) had / would have had an effect on the outcome / severity of this particular accident.

EFFICIENCY

So far efficiency quantifies the number of accidents which are likely to be influenced by the analyzed primary safety measure. So the efficiency is a proportion respectively a number. For the design or the assessment of a primary safety measure it is more important to get the two summands producing efficiency than the value for efficiency itself:

$$efficiency = proportion\ of\ avoided\ accidents + proportion\ of\ accidents\ with\ mitigated\ severity$$

The aim of primary safety measures is to prevent accidents. Thus the "proportion of avoided accidents" or the "efficiency in avoiding accidents" is the most important characteristic of a primary safety measure.

The “proportion of accidents with mitigated severity” or the “efficiency in mitigating accidents” is hardly interdependent by classification measure that describes the performance of the mitigated severity over **AoE**.

SCORE CARD “Efficiency of a primary safety measure”

Often it is more appropriate to characterize efficiency by more than one figure. To be able to do so in [9] the concept of a “Score Card Efficiency” was introduced. The “efficiency“ of a primary safety measure is described with six characteristics and a distribution. The first characteristics are the proportions where the measure has / has no benefit. The amount of benefit is subdivided in the proportion of “avoidance” and “mitigation”. The effect of mitigating accident severity is characterized by a mean value and a distribution of an appropriate physical measure – here reduced collision speed. Other measures like reduced EES, injury severity (MAIS) etc. could be used as well. The mean value could be substituted by other statistical rations like the median, min-max, average and so on. The idea is illustrated in figure 3 for an academically emergency braking system: the system is able to detect a conflict with a vehicle moving ahead, waiting or starting. When a crash is imminent, the system automatically performs a full braking 0.3 seconds before the collision. This reaction of the system is independent from driver reactions. The area of conflict which is analyzed is rear-end collision.

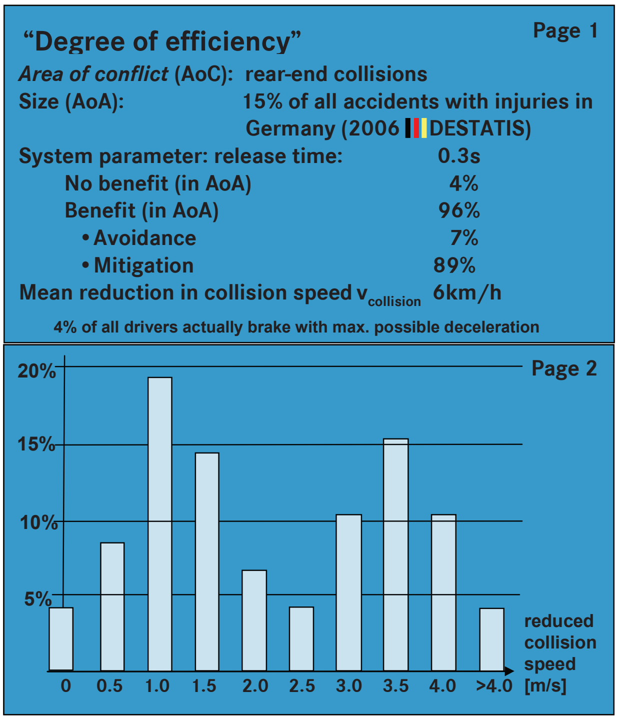

Figure 3: Score Card “Efficiency”

METHODS FOR DETERMINING EFFICIENCY

Initial findings about the methodology of retrospective and prospective analysis of secondary safety systems can be found in [18]. Secondary safety measures start working after the first contact resulting from a collision. Their aim is to reduce the consequences of an accident. In contrast primary safety measures are developed to reduce as much energy / velocity as possible in a fixed period of time before the first contact to avoid the collision. Hence an additional methodology is used for primary safety measures [20]. First of all methods for determining the efficiency of primary safety systems can initially be classified according to their ability to provide results for efficiency in a retrospective or prospective view.
Methods for a retrospect assessment of efficiency have established themselves by proving the evidence of ESP. Studies conducted by Mercedes-Benz [1], NHTSA and others show that in a representative sample of accidents a significant reduction in the number or the severity of special types of accidents between a group of cars equipped with ESP and a group of cars without ESP could be observed. One of these special types is for example the type of “driver related accidents”. Mercedes-Benz showed a reduction of 42% in this type of accident. This

result is confirmed by other studies and already existing meta-studies [2]. In contrast to [13] not a type of an accident but the conflict of a skidding car before the crash is analyzed.
The principle disadvantage of retrospect methods is that they base on the fact that there is a significant amount of cars equipped with the system in the market and that they are differentiable from those without the system. This penetration normally needs years after the point of sale. Hence a retrospective method is unacceptable in the development of effective safety systems.
The prospective methods can be distinguished by their ability to supply statistically reliable representative results. The following requirements had to be fulfilled to obtain such results:

[1] representative accident database and AoA used as a basis for the method / analysis
This means in particular a great number of total and considered accidents, surveyed coincidentally are containing all required information by the primary safety system.

[2] reproducibility of the results and the determination of AoA and AoE respectively
This means especially a strict rule-based or automated approach has to be used.

[3] integration of most / all parts of the primary safety system in the estimation of AoE
This means integrating descriptions or models for most or all parts of the system in the loop with car, driver and the complex accident situations in their holistic interactive dependencies (for the prevention of drastic simplifications) have to be made.

An assessment of common used method for predicting efficiency in the two dimensions "representative database" and "level of details of integrated parts" is shown in figure 4.
The "method" driving simulator has the unique advantage that it makes it possible to vary the driver and its behaviour in a fixed accident situation remaining the same for all different drivers. In [19] the use of a driving simulator in the development process of assisting systems is described. To cover the wide spread of conflicts that lead to a rear-end accident the efficiency is calculated as a mean of several typical rear-end accidents [3, 4, 14, 16]. A lot of sensitivity and experience is needed to gain reliable figures that describe the real life efficiency.

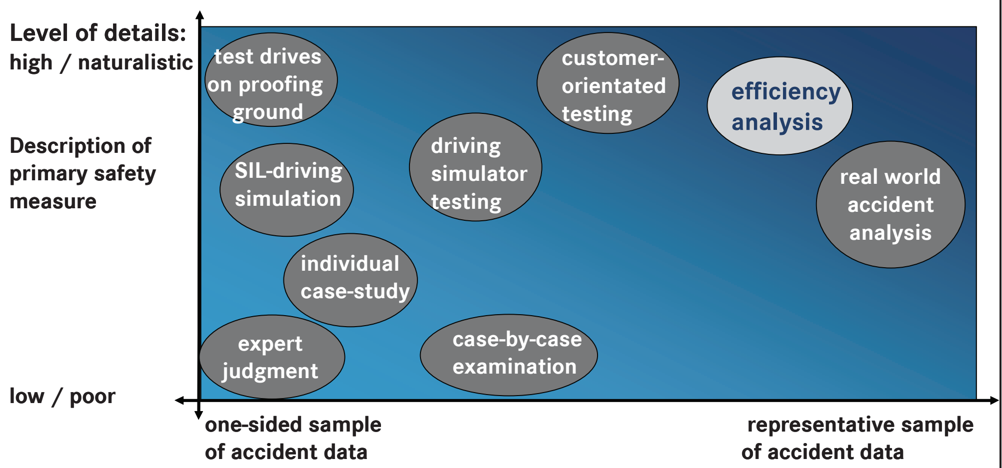

Figure 4: Efficiency assessment methods and their characteristics

For getting representative results the integration in other methods is necessary. The determination of **AoE** which is necessary to calculate **DoE** can be done in two ways. The simple way is to integrate parts of the primary safety system in the specification of **AoE**.
If **AoA** and **AoE** are determined from in-depth accident data, this could be done. An example is described in [7, 8]. A weakness of this approach is the not neglectable variance in the results. A more complex and expensive way is to determine **AoE** by an automatically performed analysis of all accidents contained in the **AoA** [8, 9]. This approach ends in a trustier **AoE** and **DoE** than the one resulting from the simplified approach described before.

A HEURISTIC TOOL

Generally, **AoA** and **AoE** give an upper and lower estimation for the exact set of accidents that are addressed by a system and where a system has definitely an influence. AoA can also be considered as the upper boundary or the optimistic approach, while AoE is the lower boundary or pessimistic / conservative approach in estimating the system's impact on the accident cases. As always, the truth lies somewhere in between, and all the more the closer those two sets are approaching each other, the more precisely the result of the efficiency analysis will be. Usually, this accuracy comes at the cost of putting more effort into the analysis and by conducting for example a case-by-case assessment of the system, which can be done manually by an expert or automated.
Another issue arises by attempting to perform an overall assessment of more than one safety system. It is clear that different systems can have areas (sets of accidents), where more than one system can have an impact on the outcome of a single accident. A simple method has to be developed to deal with this issue. This method should also fit easily into the current framework for efficiency analysis of a single system. One solution is shown in figure 5.

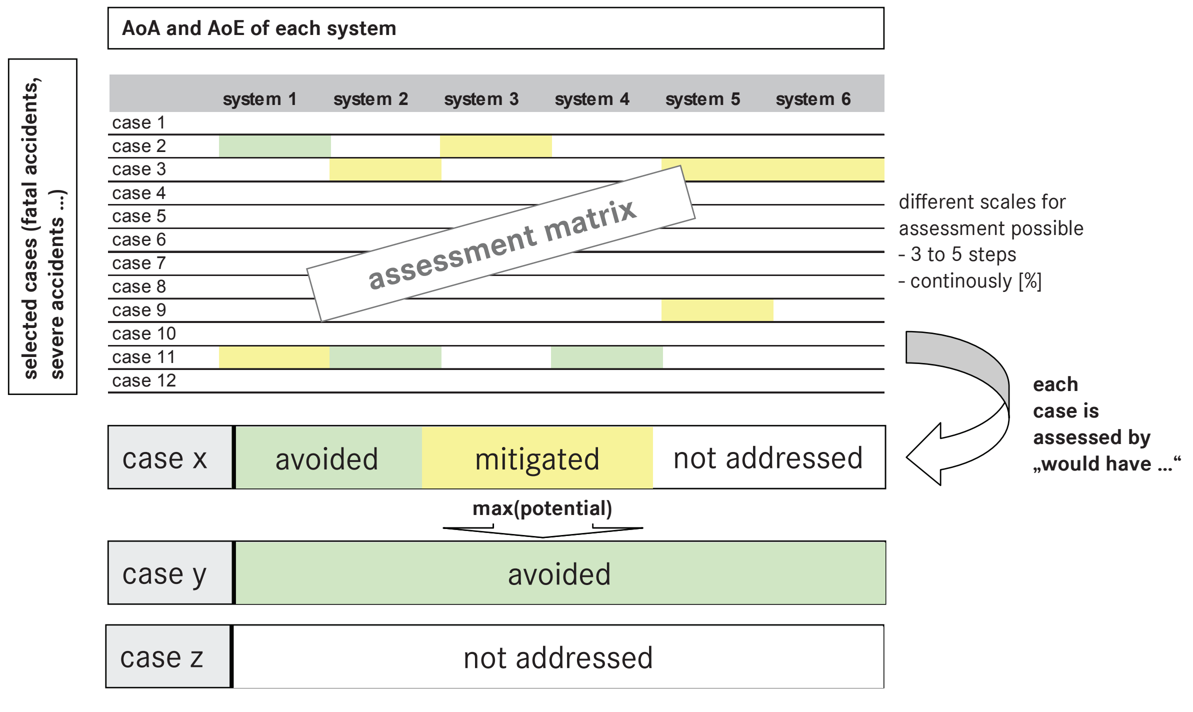

Figure 5: Assessment of more than one system at once

The columns of the assessment matrix are spanned by the list of systems that should be assessed. Each row represents an accident in the area of reference. In the process of assessment, each system in each accident has to be assigned a value of effectiveness of the system. This value is within a pre-defined scale which consists in its simplest form of the three values: "avoided", "mitigated", and "not addressed". The assignment can be accomplished by three different methods or by a combination of them:

1. Selection of cases in the database according to system correlated restraints: This is the easiest method and only works, if the parameters, that specify the constraints to make a valid decision, if the system is activated or not, can be mapped properly to values in the underlying accident database.

2. Case reconstruction:
Very often, a simple mapping to values in the database is not sufficient for a valid assessment of the situation with respect to a specific safety system. One needs to do a reconstruction of the case to see its outcome.
3. Case-by-case analysis based on expert assessment:
If no formal rules can be established to make a decision of the efficiency of a system in an accident, an overall assessment of the case needs to be done by judging from an expert's point of view or by discussing in a group of experts. However, this is the most time-consuming method and needs to the expertise and background of experts although it somehow has lack of reproducibility.

After having assigned a "multi-system" assessment of the potential to avoid or mitigate each single accident in the database, an overall value for both, conservative and optimistic efficiency can be determined in the already described way above. As a bonus, all cases with no potential effect of any of the systems are returned in this process. These cases can be seen as the blank spots on the map of accidents and can form a good starting point for future developments in traffic safety.

DATABASES

The choice of the accident data base used for an efficiency analysis for a primary safety measure determines whether the results can be applied to official accident statistics or not.
For Mercedes-Benz the reflection of these figures by real world accident statistics is an essential benchmark for judging the system's efficiency. A multiplicity of different accident data collections are used for analyzing the potential benefit of a primary safety measure. Common used collections came from police departments, insurance companies, unions of forensic accident assessors or accident research department of automotive manufacturers. All of these samples result from a special focus of their acquisition respectively the aim of the underlying survey. To perform a survey representatively (from their focus) for e.g. all accidents in Germany is not a requirement for all mentioned investigations.
Representativity of an accident data base means that its composition and characteristics resemble (of a defined severity) with the composition and characteristics of the allocation base – here the entirety of all accidents e.g. in Germany. In other words a smaller sample set (accident data base) is a consistent image of the big allocation base. It is a popular fallacy that representativeness of an accident data base correlates respectively growths with its size. This is only true for a data base that consists of an undistorted sample of accidents. Here a minimum number of samples that could be analyzed are needed to become statistical significant. For a distorted respectively focused selection increasing samples size tightened its missing representativeness.
Representativity of an accident data base is the basis to be able to educe universally valid evidences for the entirety of all accidents from analyzing a smaller (but representative) image established in the accident data base. The GIDAS data base is proved to be representative for accidents with injuries (and fatalities) in Germany. This is why GIDAS is used in this paper.

GIDAS DATABASE - A STATISTICAL REPRESENTATIVE SAMPLE OF ACCIDENTS

The analysis in this paper is based on accident data provided by the GIDAS project. GIDAS is an abbreviation for "German In-Depth Accident Study". GIDAS is a cooperative project between the German Association for Automotive Technology Research (Forschungs-vereinigung Automobiltechnik e.V., FAT) and the German Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt) (see [11] for more details). In its current form it was founded in 1999. Since this time the data for in-depth documentations of more than 2000 accidents per year is collected in two research areas – the metropolitan areas around Hanover and Dresden – see figure 6.

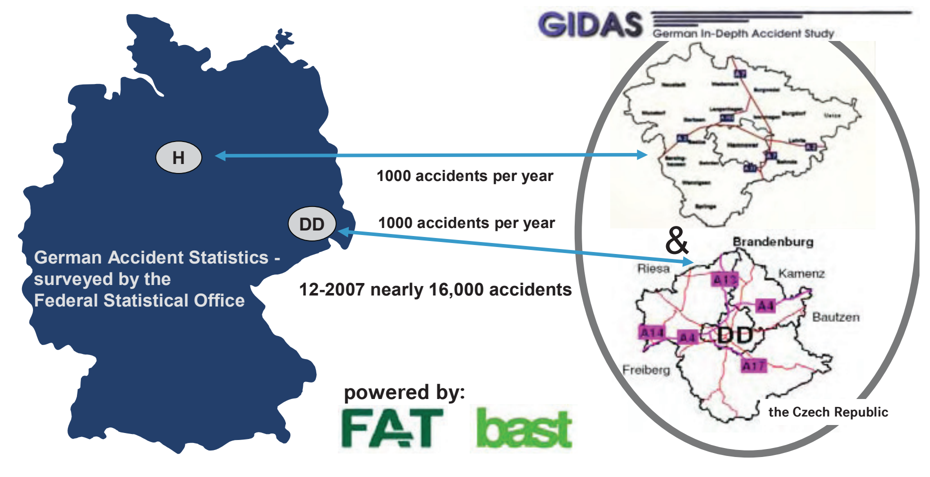

Figure 6: GIDAS database - the research areas around Hanover and Dresden

The criterions for choice and collection are: (1) road accident, (2) accident in one of the research areas, (3) accident occurs when a team is on duty in a defined timeframe, and (4) at least one person in the accident is injured, regardless of severity. For each accident a digital folder is delivered according to carefully defined guidelines and coded in a database. Depending on the type of accident, each case is described by a total of 500 to 3,000 variables, containing e.g. accident type and environmental conditions (the type of road, number of lanes, width, surface, weather conditions, time of the day,…) surroundings of the accident scene, vehicle-type, vehicle specifications (mass, power, tires, …) and configurations (e.g. with safety measures), documentation of damage of the vehicles and injury data for all persons involved and their medical care. Investigation of all cases is "on the spot" to ensure best visibility of traces for a best possible reconstruction. Each accident is reconstructed in detail including the pre-collision-phase. Available information includes initial vehicle and collision impact speed, deceleration as well as the speed sequence of the collision.
Half the battle of the pro of this database is that: (1) for standard AoA´s (needed for the assessment of actual safety measures) the number of cases is high enough to provide statistically significant results, and (2) each accident is documented in great detail, including in-depth-analyses and reconstructions of the course of the accidents including the pre-crash phase, and (3) most of all this database is proven to be representative to German national accident statistics.

EFFICIENCY OF SERIES "SINGLE" AND "MULTI" PRIMARY-SAFETY-SYSTEMS

Development objective for primary safety measure is the avoidance of accidents. But avoided accidents are not contained in an accident data base. Thus the efficiency of a primary safety measure in contrast to a secondary safety measure can not be determined directly from accident data. By construction **AoE = AoA** gives an upper limit for the efficiency with the assumption that the **DoE** equals 100%. A better estimation can be obtained by integrating the range of operation or system boundaries of the primary safety measure in the determination of **AoE**. This gives a better upper bound for **DoE** than **AoA** itself.
("Single") Primary safety measures could be categorized by "always-on" respectively "manual-on" systems. A special case is established by "operated-on" systems. Examples for "always-on" primary safety measures are ABS, ESP, and BAS, an example for a "manual-on" measure are daylight running lights. Series vehicles did not have one system of primary safety but a combination of systems referred to as "multi" measures. Particularly with regard to

determining efficiency in avoiding or mitigating the severity of accidents, it is useful to distinguish between cooperative, competing and non-effecting primary safety measures. In the case of rear-end accidents an example for cooperating systems is the combination of (switched-on) ACC and an emergency brake or a Brake Assist (BAS), an example for competing systems is ESP and ABS or BAS in the case of skidding, an example of non-effecting measures is the combination of daylight running lamps and flashing brake lights in the first car. In the first example the efficiency in avoiding accidents is greater than the sum of the single values, in the second it is less then the sum and in the last case it is the maximum of the single values.
By so far driver behavior is not consequently modeled. This is why assumptions about this had to be made, e.g. reactions on warnings, behavior in critical situations, switching on systems and so on. This leads to different scenarios, which can be optimistic or conservative.

EXAMPLE – EFFICIENCY FOR AN ACTUAL MULTI PRIMARY SAFETY MEASURE

To make the definitions and methods presented before more clearly an example is discussed next. The combination of DISTRONIC PLUS and Brake Assist PLUS has been chosen for this example. It is adopted from [20] where it is explained in more detail. This combination or "multi" primary safety measure addresses rear-end collisions. A collision with a vehicle moving ahead, waiting or starting is very common. In Germany each sixth accident with injuries and each sixteenth accident with fatalities is a rear-end collision see figure 7. What is the expected efficiency from the combination of DISTRONIC PLUS and Brake Assist PLUS in these kinds of accidents?

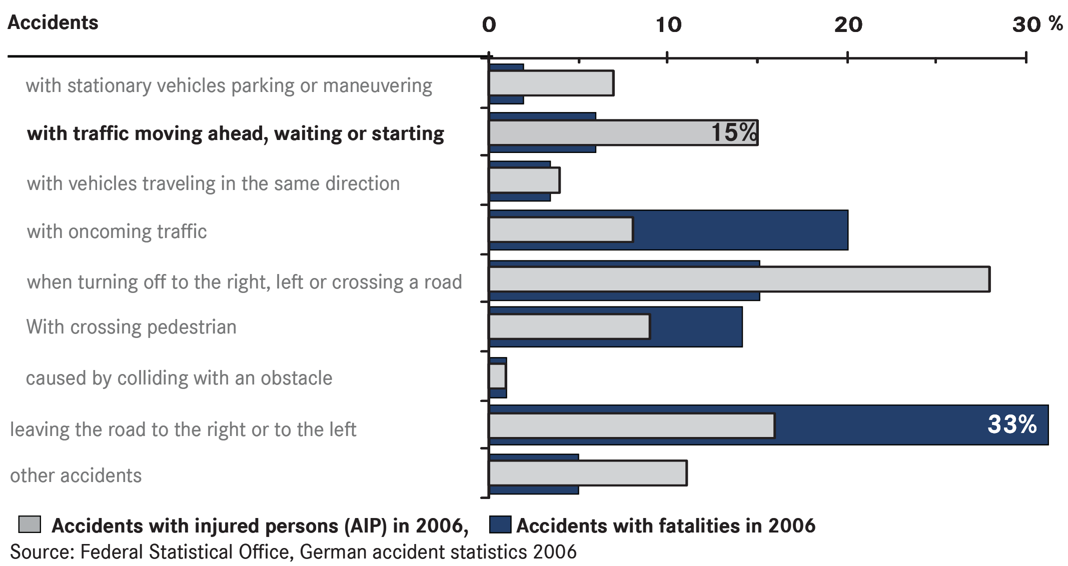

Figure 7: Distribution of different accident types with injured persons or fatalities in Germany 2006
(Source: Statistisches Bundesamt, Fachserie 8, Reihe 7, 2007)

Selective further developments of the advanced cruise control system (ACC) of Mercedes-Benz called DISTRONIC lead to the new system DISTRONIC PLUS in 2005. A relevant improvement was the integration of two radar sensors systems to monitor and evaluate the traffic situation in front of the car. The 77 GHz DISTRONIC radar was combined with two 24 GHz short range radar sensors. The 77-GHz long-range radar is able to scan three lanes over a distance up to 150 meters with an angle of nine degrees. Two 24-GHz radar sensors monitor the immediate area in front of the vehicle from 0.2 up to 30 meter with an angle of 80 degrees. The algorithms for situation perception and assessment were enhanced. This leads to an increased operating range from 0 km/h to 200 km/h, an extension of the area of operation of the distance control from 0.2 m up to 150 m and an advanced dynamic range for deceleration from 4m/s² to 2m/s². DISTRONIC PLUS is supplemented by an increasing number of primary safety measures that share the sensors with DISTRONIC PLUS and implement an additional safety feature. Brake Assist PLUS (BAS PLUS) is one of them. The BAS PLUS system is an additional option efficient especially in the case of rear-end collisions; naturally the (classic) BAS remains available. With this radar-based environmental perception the situation evaluation algorithm of BAS PLUS can detect imminent rear-end collisions with identified obstacles. If there is currently one detected:

(1) BAS PLUS calculates continuously the actual braking assistance required to avoid the collision by target braking (not necessarily a full braking).

(2) BAS PLUS warns the driver with an audible signal, prompting him to take action.

Brake Assist PLUS is an "always-on" system while DISTRONIC PLUS is a "manual-on" system. Both complement each other if DISTRONIC PLUS is switched-on. The combination of both systems is not a single but a "cooperating" multi system. Its efficiency is more than the sum of both efficiencies.

The assumptions on which the following efficiency analysis is based are very important, they are chosen to be very conservative: Selecting accidents from GIDAS **database** (2006) that belong to "Area of Action – all rear end collisions with injuries, in which a passenger car collides with another vehicle in front" as defined before. Then **AoA**:

- consists of 839 in-depth evaluated accidents, especially containing reconstruction data
- constitutes a representative sample of rear-end accidents with injured persons in Germany

The systems DISTRONIC PLUS and BAS PLUS were tested virtually in a conservative scenario assuming:

- Equipment rate is 0% or 100%.
- BAS PLUS is activated permanently (rate of switching-on is 100%).
- DISTRONIC PLUS - is activated for 100% extra urban driving on freeways (BAB – for "Autobahnen") and highways (B – for "Bundesstraßen").
- Conservative assumptions with respect to the behaviour of the driver during the accident:
  - Driver behaviour remains UNCHANGED during the accident (equal to reconstruction).
  - A possible reaction of the driver to all kinds of collision warnings is NOT MODELED.
  - A simple driver model for activating BAS is used.

To clarify the definitions introduced before examples for their usage are given here. The result of the "testing" is the "area of efficiency - **AoE**". The "degree of efficiency" **DoE** is what is depicted in figure 7. Additionally **DoE** is subdivided in the proportion of mitigated (**DoM**) and avoided (**DoA**) accidents. Three single cases were analysed. These cases arise from three different "Areas of References - **AoR**". In the first case **AoR** is equivalent to all accidents with injuries. In the second case **AoR** is equivalent to all accidents with injuries extra urban on freeways and motorways, in the last case the restriction is on all accidents with injuries extra urban on freeways only.

With this conservatively defined scenario a lower limit for the efficiency of the combination of DISTRONIC PLUS and Break Assist PLUS in the case of rear-end accidents in Germany assuming a penetration rate of 100% is gained. The results were taken from [20].

The results show that DISTRONIC PLUS and Brake Assist PLUS complement one another in a perfect way, provided that DISTRONIC PLUS is switched on.

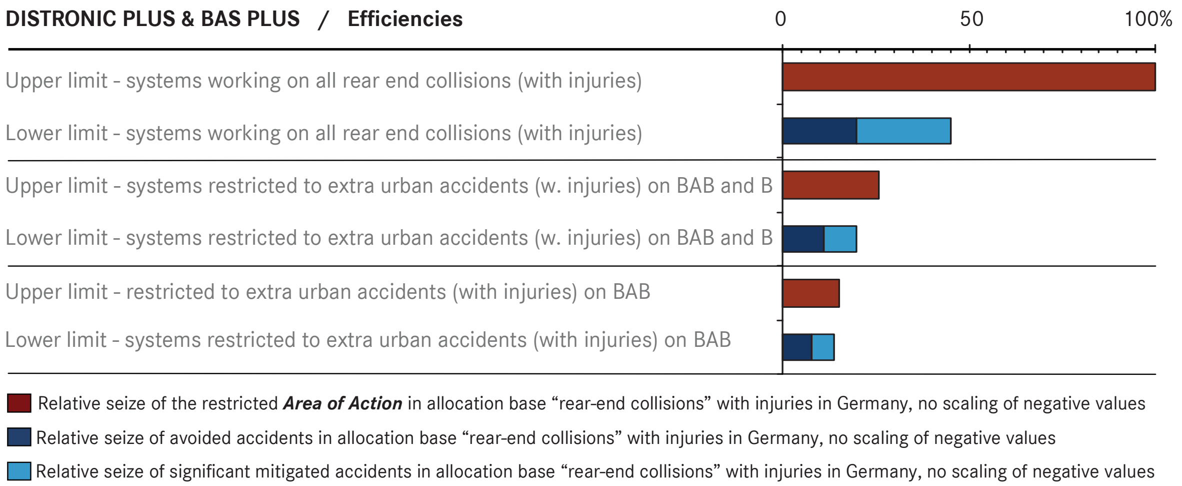

Figure 8: Limits fort he efficiency of the „multi" measures DISTRONIC PLUS and Brake Assist PLUS in German rear-end collisions with injured persons.

DISTRONIC is designed for keeping a chosen distance to a vehicle in front – if possible, with the desired speed, - if not possible, with a speed resulting from keeping the distance having higher priority. The recommended field of application for DISTRONIC is extra urban on freeways and highways. That is why these cases were regarded here explicitly. The results show that the combination of both systems is highly efficient in extra urban while using DISTRONIC PLUS. The value of the efficiency in all rear-end crashes in figure 8 is recognisable influenced by the amount of completed cases with fragmentary data.

CONCLUDING REMARKS

The range of methods used to estimate "efficiencies" for primary safety measures is wide. It varies from "crystal ball" expert judgement to technically high sophisticated simulation techniques. The aim of this paper is to introduce and harmonize definitions for common used notations to get an abstract concept for the "efficiency" of a primary safety measure. The resulting benefit of these measures in real world accidents has a high relevance in different topics and is used by miscellaneous stakeholders. To increase automotive safety actually it is important that the predicted efficiency can be assigned to the real life accident world mapped itself to national accident statistics. It is shown that representativeness of the (predicted) efficiency is the key request to get statistically reliable results as stipulated before. This requirement puts high demands on the used method. Necessary constraints for a potential method like using a representative accident data base, reproducibility of the results, integratability of detailed components of the primary safety measure were discussed. The paper ends by applying a presented method to determine the efficiency of a "multi" measure consisting of DISTRONIC PLUS and Brake Assist PLUS, two realistic assisting systems purchasable for Mercedes-Benz S- and (soon coming new) E-class. High demands should be taken on the accurateness of a detailed modelling of components of a primary safety measure like environment perception, sensors and functionality but also on vehicle dynamics and the situation itself. A holistic approach and a close multidisciplinary collaboration of different specialisms are needed. An accident researcher as well as an expert on assisting systems, simulation, ergonomics or vehicle dynamics working on their own will produce insufficient results. Therefore Mercedes-Benz established an interdisciplinary team of experts to manage this demand. The requirement for a representative prospective "efficiency" of a primary safety measure sets the standard up another notch. From an automotive manufacturers point of view this request is necessary to obtain the reliability needed for its far reaching consequences.

REFERENCES

[1] Breuer, J., Eckstein, L., Frank, P., Unselt, T.: Avoidance of „loss of control accidents“ through the benefit of ESP, FISITA 2004 World Congress, Barcelona

[2] Erke, A.: Effects of electronic stability control (ESC) on accidents: A review of empirical evidence, AAP, Vol. 40, p. 167-173, 2008

[3] Breuer, J., Gleisner, S:, New Systems to avoid/mitigate rear-end collisions, VDI- Berichte Nr. 1960, p. 393 – 402, Düsseldorf, 2006

[4] ATZ-Extra, Die neue S_Klasse von Mercedes-Benz, ATZ-Sonderheft 10/2005

[5] Fach, M., Baumann, F., Nüssle, M., u. a.: Objektive Bewertungsverfahren für radbremsen-basierte Systeme der Aktiven Sicherheit, 25. Int. µ-Symposium, p. 56-80, Darmstadt, 2005

[6] Gleissner, S., Heine, U., Hillenbrand, J.: Driver Assistance Systems for Active Safety in Mercedes-Benz Passenger Cars, FISITA-Congress 2008, F2008-08-047, 2008.

[7] Gottselig, B., Eis, V. Sferco, R.,: Entwicklung der Verkehrssicherheit – Potentialbestimmung von modernen Sicherheitssystemen, VDA-Kongress 2008, Leonberg, VDA

[8] Becker, H., Busch, S., Zobel, R.: Methods for the evaluation of primary safety measures by means of accident research, FISITA 2004 World Congress, F2004-V039, Barcelona, 2004

[9] Schittenhelm, H.: Predicting the efficiency of collision mitigation strategies with respect to real world accidents, 3. Tagung „Aktive Sicherheit durch Fahrerassistenz“, TÜV Süd, 2008 http://www.fahrzeugtechnik-muenchen.de/component/option,com_docman/task,cat_view/gid,37/Itemid,86/lang,de/

[10] Scheunert, D., Sferco, R., Becker, H.: Unfallforschung – wo liegen die Potentiale?, Verband der Automobilindustrie (VDA), VDA - Technischer Kongress 2002, Proceedings, Stuttgart, 2002

[11] WWW.GIDAS.ORG

[12] Breuer, J. Eckstein, L., Unselt, T.: Fußgängerschutz durch Bremsassistenz, 1. Tagung „Aktive Sicherheit durch Fahrerassistenz“, TU München und TÜV Süd, 2004

[13] Scheef, J., Strutz, T., Zobel, R.: What accident analysis tells us about safety evaluations of passenger vehicles, ESV-Congress 2007, Paper-No. 07-0074.

[14] Zomotor, A.: Verhalten von Kraftfahrern in Notsituationen, in Krochmann (Ed), Reaktionszeiten von Kraftfahrern, TU Berlin, 1979

[15] Schittenhelm, H.: Fahrerverhalten und Reaktionen in kritischen Fahrsituationen, VDI-Tagung „Innovativer Insassen und Partnerschutz“, VDI-Berichte 1911, Berlin, 2005

[16] Schittenhelm, H., Ammon, D., Apel, A., Mitschke, M.; Driver behaviour model for longitudinal and lateral control in emergency manoeuvres, EAEC Congress 1995, SIA9506C12, Strasburg

[17] Schöneburg, R., Breitling, T.: Enhancement of active and passive safety by future pre-safe systems, Paper No. 05-0080, ESV-Conference 2005, Nagoya, 2005

[18] Bakker, J., Herrmann, R.: Systematik zur Ermittlung der Wirksamkeit von Fahrzeugsicherheits-maßnahmen auf der Grundlage von deutschen Unfalldatenbanken. Innovativer Kfz-Insassen- und Partnerschutz VDI – Gesellschaft Fahrzeug- und Verkehrstechnik, 2001.

[19] Frank, P., Reichelt, W.: Fahrerassistenzsysteme im Entwicklungsprozess in der Kraftfahrzeug-führung, Ed. Timpe, K.-P., p. 71-78, Springer, Berlin,2001

[20] Schittenhelm, H.: Design of effective collision mitigation systems and prediction of their statistical efficiency to avoid or mitigate real world accidents, FISITA Congress 2008, paper F2008-08-109, München, 2008