THE REQUIREMENTS FOR DRIVER ASSISTANCE SYSTEMS AND THEIR EFFECTS ON REAL-LIFE ACCIDENTS

K. Langwieder
German Insurance Association
Institute for Vehicle Safety
U. Frost
Dr. Brenner & Münnich Ingenieurgesellschaft
E. Bach
University of Applied Science Dresden
Germany
Paper Number 98-S2-W-33

ABSTRACT

The development of electronic systems in cars is strongly increasing and especially driver assistance systems will be available in a short time. Therefore their effectiveness in accident avoidance related to defined critical situations and their influence on driver behaviour has to be analysed.

On the basis of the GDV large scale accident material an assessment has been made which part of car crashes with personal injury could be influenced by driver assistent systems. This paper presents the results of the first research phase.

INTRODUCTION

In the past few decades, great success has been achieved in Europe in the field of traffic safety. Without it, the number of road casualties and follow-up costs would be much greater today. In the last few years, developments aimed at improving both traffic flow and traffic safety have concentrated on collective information and guide systems. In the area of automotive engineering in particular, passive vehicle safety has been improved.

Accompanied by the rapid development of microelectronics, individual information and control systems are gaining in importance. They are usually linked to one particular vehicle and assist the driver in complex motoring situations which are objectively difficult to assess, perhaps even critical. They are intended to ensure that the constant increase in traffic volume is dealt with in a safe and efficient manner within an infrastructure that is only capable of limited expansion and development.

The present paper is devoted to driver assistance systems and their contribution to traffic safety. It concentrates in particular on the system of adaptive cruise control (ACC) which is intended to increase vehicle comfort and to reduce the number of rear-end accidents (REA). The example of rear-end accidents is used to illustrate the general requirements that an adaptive cruise control system must fulfill in order to function properly, i.e. prevent accidents.

The accident data used in this paper originates from real traffic accidents in Germany which have been documented by records and protocols from the police, third party insurance companies, district attorneys and public prosecutors, by photographs, expert opinions and witness testimony. Two GDV accident databases were used which were created in connection with a representative survey of vehicle safety /1/ and of autobahn accidents resulting in death /2/. These statistics comprise a total of more than 7000 rear-end accidents – all of them involving personal injury. These statistics have been evaluated several times by different authors, refer in this context to the bibliography. In addition, the results of the official accident statistics for Germany, which are published annually, have been used to supplement the above material /3/.

Adaptive cruise control is a radar-assisted system designed to regulate the spacing between the driver's own car and a vehicle in front of it (Figure 1). The system recognizes the vehicles in front and regulates the speed of the driver's car whenever the driver's car fails to maintain a calculated safety margin. The safety margin is calculated taking weather conditions, road conditions and speed into account. The safety margin is adjusted on the basis of a braking deceleration that does not exceed a maximum of 2 m/s^2.

The stage of development (stage 1) now achieved by the adaptive cruise control system recognizes vehicles in front that are traveling at a speed of at least 40 km/h. Slowly moving vehicles, turning and stationary vehicles are not identified, nor are pedestrians, cyclists and objects at the roadside. Test series and field tests using ACC prototypes installed in standard cars are currently being conducted in Germany. The development of driver assistance systems is intended to enhance both individual motoring comfort as well as general traffic safety at one and the same time.

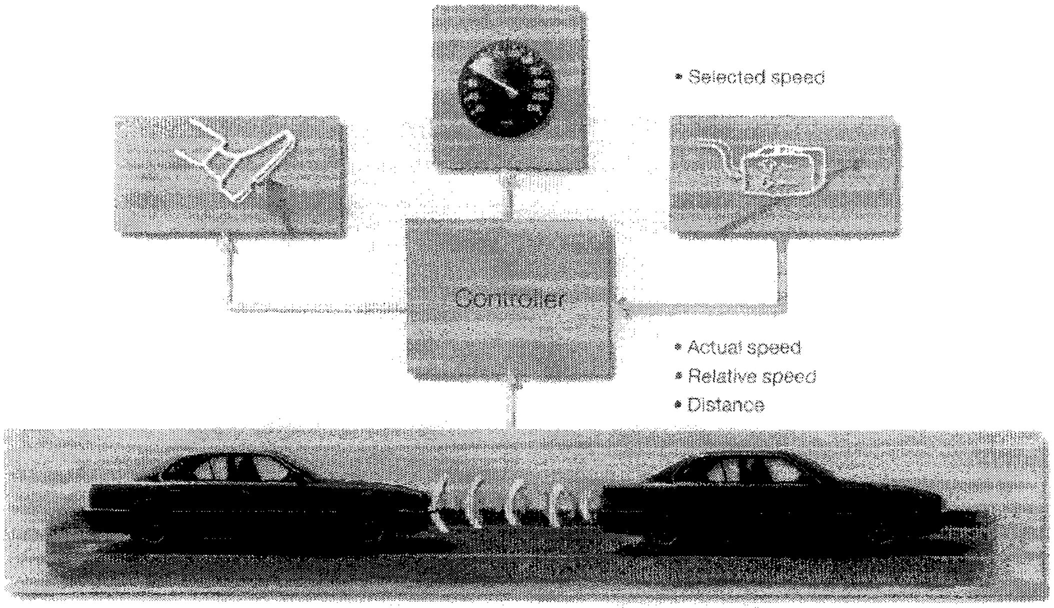


Figure 1. Adaptive cruise control – main components (BMW AG, 1996)

TRAFFIC ACCIDENTS IN GERMANY

General results - There were approximately 50 million motor vehicles on the roads in 1995, of which approximately 41 million were automobiles. The annual distance traveled by all motor vehicles totaled 603.5 billion kilometers, 180.9 billion km (30 %) of which on German highways (the autobahn). Police authorities registered a total of 2.27 million traffic accidents nationwide in 1996, of which 1.90 million accidents involved only material damage and 0.37 million personal injury.

The official accident statistics /3/ reveal the following events which, generally speaking, lead or have led to accidents (all types of accidents). These statistics also apply to rear-end collisions as well in the broader sense of the word.

- Young persons between 18-25 years of age are by far the most endangered motorists. Based on a population of 100,000, this age group have accidents approximately three times more frequently than subsequent age groups.

- About double as many men are involved in car accidents than women (both as persons causing accidents as well as persons involved in accidents). In the age group of young drivers (18-25 years of age), men caused accidents in more than 70% of all cases.
- Based on total kilometers traveled, the number of persons involved in accidents has remained at the same level in the last few years, whereas the number of fatalities and serious injuries has declined.
- An inadequate safety margin is cited with varying degree of frequency in police accident records as the main error committed by car drivers. The percentage of accidents involving personal injury on the German autobahn is 19 % and on country roads 8 %. As far as the age distribution is concerned, there is an accumulation among drivers 18-21 years old and among drivers 45 years and older (Figure 2).

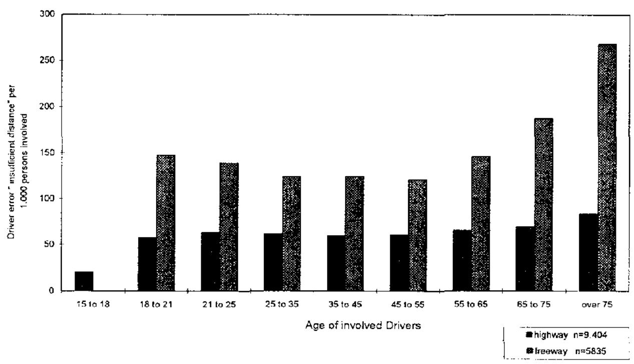


Figure 2. Drivers' error "inadequate safety margin" per 1,000 involved persons /3/

- Approximately 35 % of all autobahn accidents registered by the police occur in zones with speed limits (v = 60 - 130 km/h) and 5 % in or near construction sites.
- As far as lighting conditions are concerned, 2/3 of all accidents involving personal injury occur during the day and 1/3 at night. These statistics are equally applicable to country roads and the autobahn network.
- Approximately 0,5 % of all accidents involving personal injury outside of town (autobahn and country roads) were accidents that took place in fog.
- Less than 1 % of all accidents involving personal injury could be attributed to technical defects on the vehicle itself.

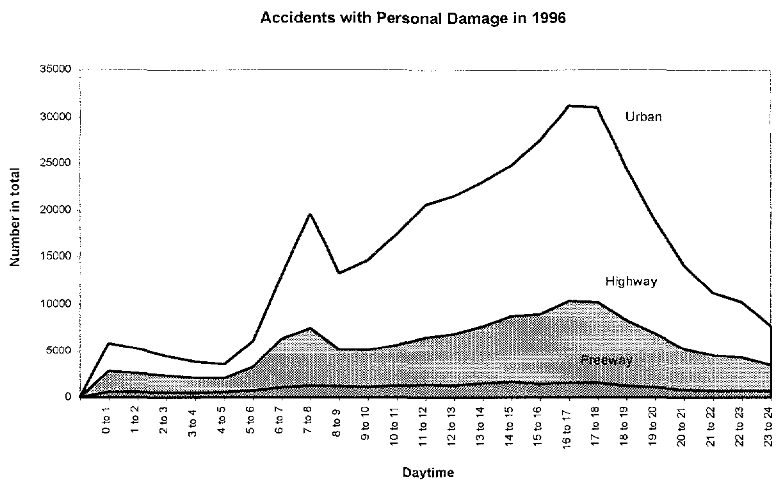


Figure 3. Distribution of accidents involving personal injury over daytime

Rear-end accidents - Rear-end accidents can be filtered out of the official accident statistics /3/ by breaking down traffic accidents according to the type of accident. Rear-end accidents belong either to accident type 1 (collision with another vehicle which starts, stops or is stationary in quiet traffic) or to accident type 2 (collision with another vehicle traveling in front or with a stationary vehicle).

According to the traffic conditions rear-end accidents are predominant among autobahn accidents (Table 1). Almost every other autobahn accident involving personal injury is a rear-end accident (46 %) and almost one out of every four accidents (21 %) is an accident involving serious material damage.

Of the total number of accidents that occurred in Germany in 1996, police registered

14,866 rear-end autobahn accidents, 11,363 of these involving personal injury,

and

20,553 rear-end accidents on country roads, 17,776 of these involving personal injury.

A total of 55,976 rear-end accidents involving personal injury occurred within city limits, thus accounting for 24 % of all accidents involving personal injury within city limits.

Table 1-a
Rear-end accidents involving serious material damage in 1996 according to location /3/

Type of Accident	Urban		Country Roads		Autobahn		Total	
	abs.	%	abs.	%	abs.	%	abs.	%
Rear-end Accidents	9.379	14,5	2.777	7,4	3.503	20,6	15.659	13,1
Others	55.446	85,5	34.608	92,6	13.467	79,4	103.521	86,9
Total	64.825	100	37.385	100	16.970	100	119.180	100

Table 1-b
Rear-end accidents involving personal injury in 1996 according to location /3/

Type of Accident	Urban		Country roads		Autobahn		Total	
	abs.	%	abs.	%	abs.	%	abs.	%
Rear-end accidents	55.976	24	17.776	16	11.363	46	85.115	23
Others	180.033	76	94.321	84	13.613	54	287.967	77
Total	236.009	100	112.097	100	24.976	100	373.082	100

Analysis Of Rear-End Accidents

Responsible vehicle drivers - Men predominate the picture both in the case of rear-end accidents as well as in other types of accidents. Approximately 70 % of the persons causing rear-end accidents are men.

As far as the age distribution is concerned, drivers up to 30 years of age are the predominant factor in the case of rear-end accidents. They are responsible for almost 50 % of all persons involved in rear-end accidents. Based on the ratio of responsible drivers to participants, elderly drivers (60 years and older) are conspicuous in addition to young drivers up to 25 years of age (Figure 4).

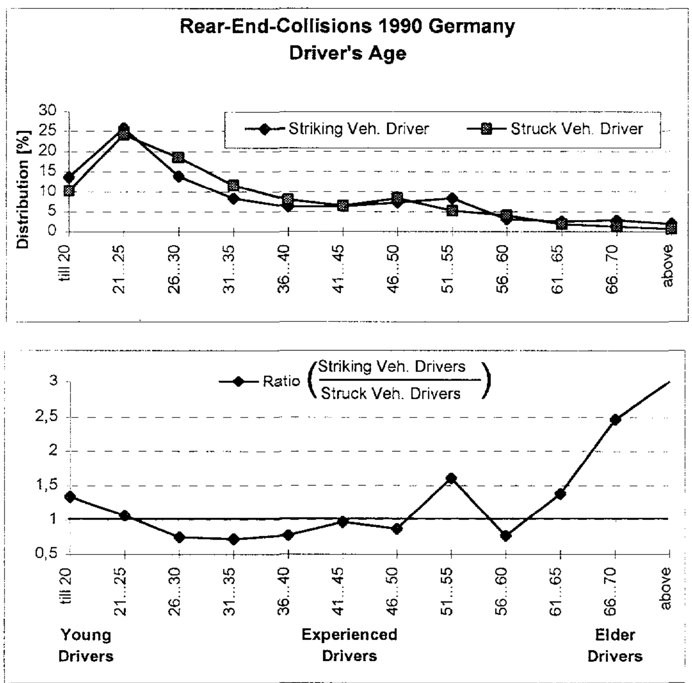


Figure 4. Driver's age in rear-end accidents in Germany

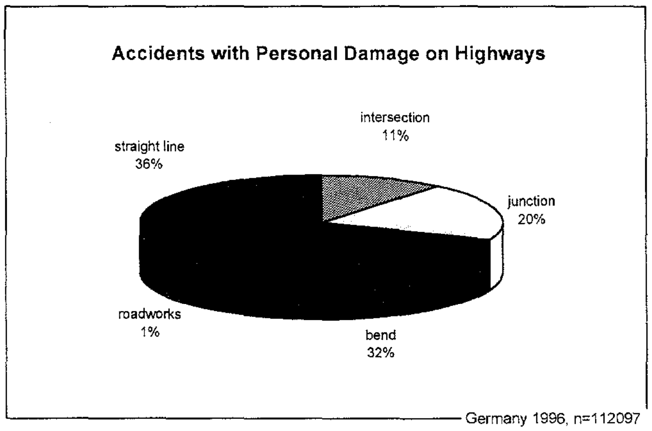
Road category - Based on known findings, severe rear-end accidents involving personal injury (refer to Table 1a) occur

- in 66 % of all cases on streets within city limits,
- in 21 % on country roads and
- in 13 % on the autobahn.

Attendant circumstances - The majority of rear-end autobahn accidents happen on straight sections of road (75 %), whereas curves and junctions are where most accidents occur on country roads (approx. 30 % in each case), refer to Figure 5.

As far as the light and road conditions are concerned, most rear-end accidents occur on dry pavement:

Pavement		Light	Percentage
dry	and	light	41 %
dry	and	dark	29 %
wet	and	light	14 %
wet	and	dark	16 %



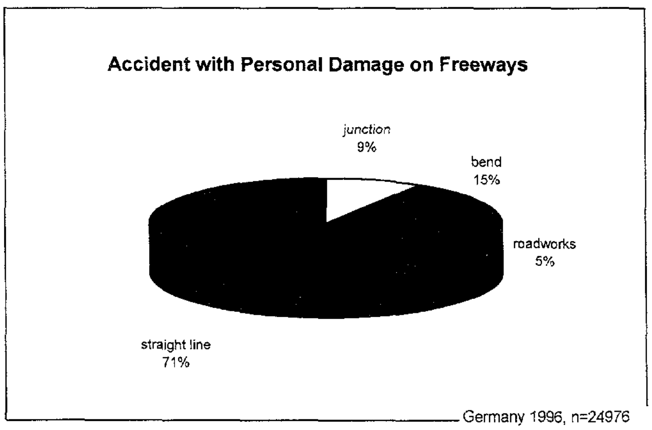


Figure 5: Site of rear-end accidents /3/

When the factors underlying the accident data were analyzed, there were no indications the conditions of light and pavement were significant, although visibility was classified into two categories: clear and obscured /4/.

Involved vehicles - The evaluation of the data has provided the following indications as far as the vehicles involved in two-car rear-end accidents are concerned:

- half of the vehicles involved had a vehicle weight of ≤1000 kg (Figure 6).
- smaller vehicles (≤ 1100 kg vehicle weight, ≤ 55 kW engine rating) are more frequently the involved vehicle (the rear-ended vehicle) in their class; larger vehicles (≥ 1400 kg vehicle weight, ≥ 90 kW engine rating) are more frequently the cause of the accident (the rear-ending vehicle).
- There are indications that older vehicles are more frequently the cause of the accident in their age class. The statistical data, however, does not allow reliable conclusions to be drawn (Figure 7).

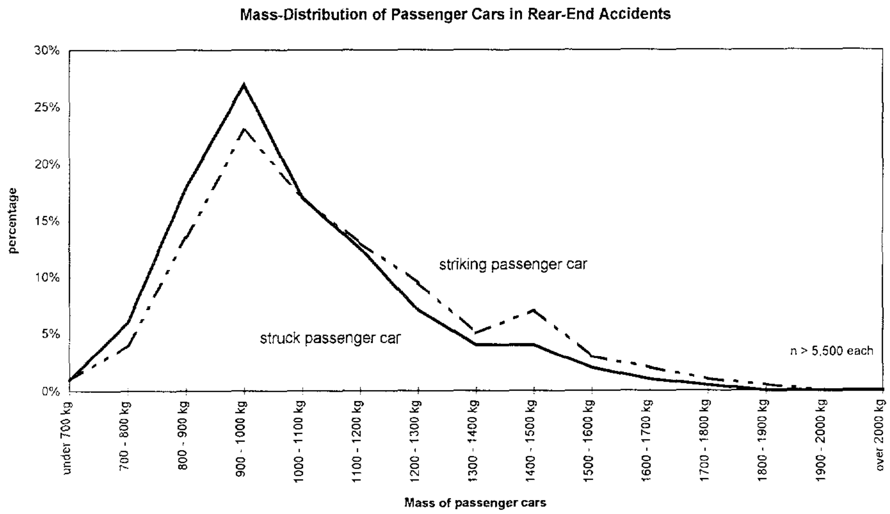


Figure 6. Passenger car mass distribution for rear-end accidents /5/

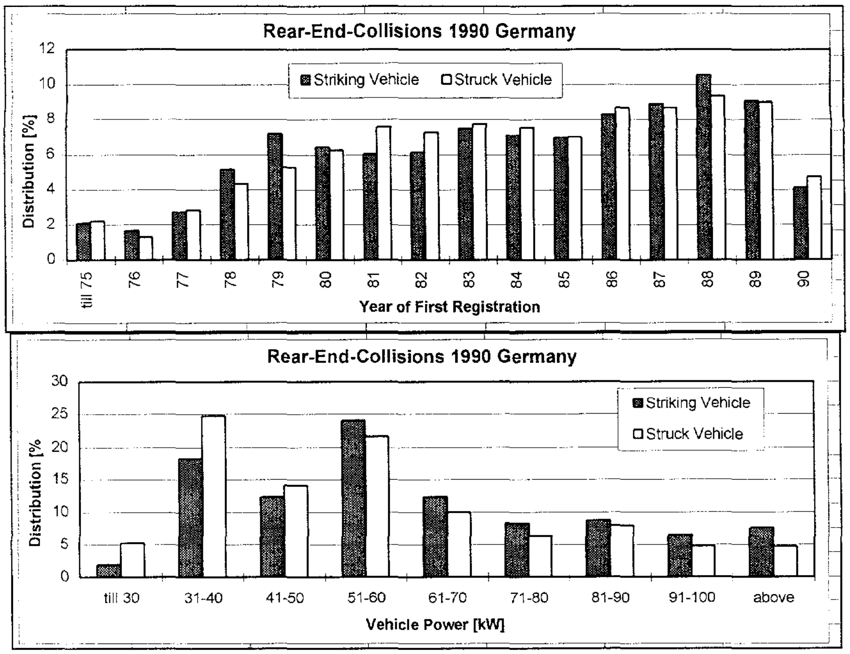


Figure 7. Passenger vehicles (model/year and power) involved in rear-end accidents (in Germany)

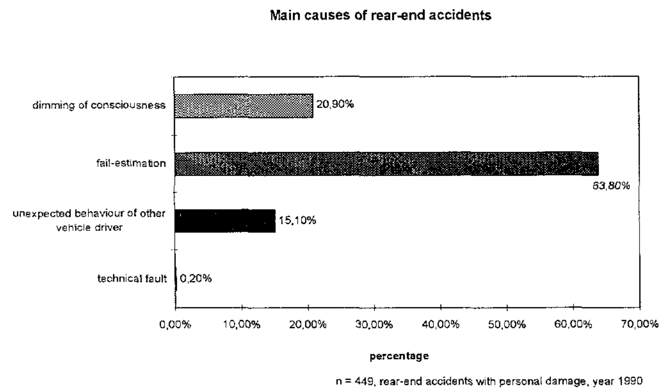


Figure 8: Main causes of rear-end accidents /5/

Causes - A random sampling of 520 rear-end accidents (two-car accidents involving personal injury) indicated the following main causes of accidents (Figure 8):

- Driver misjudgment	64.7 %
- Distraction/clouded awareness	20.9 %
- Unpredictable behavior	15.1 %
- Technical defects	0.2 %

The cases designated "driver misjudgment" means in the majority of cases that the driver "overlooked" the stopped or turning vehicle in front of his vehicle. In many cases, a stationary vehicle was recognized, but only when it was already too late. There is not an insignificant number of cases in which drivers are distracted by an accident, by tuning the radio or by children in the car. The unpredictable behavior of other motorists plays a causal role in 15 % of the rear-end accidents in this study. Technical defects are insignificant both here as well as in other types of accident.

Based on the known findings, it is obvious that rear-end accidents are caused for the most part by inattentiveness and are not due to external, unavoidable circumstances.

When drawing up police reports about accidents, the police have attributed the error of inadequate safety margin to more and more young and elderly persons causing accidents, refer also to Figure 2.

Driving and collision speed - Statements about the speed of a vehicle prior to a two-car rear-end collision show that the person who rear-ends a vehicle ahead of him ($v > 0$ km/h) was traveling at the following speeds prior to the accident:

- $v \geq 40$ km/h	100 %
- $v \geq 80$ km/h	80 %
- $v \geq 100$ km/h	60 %.

A comparison of driving speeds (Figure 9) reveals that in approximately half of all cases the differences amounted to between 20 and 40 km/h. The differences in speed are greater on country roads than on the autobahn /4/.

The deformations of the vehicles involved in rear-end accidents can be used to determine the difference in speed at the time of the collision v_{coll} /5/. Accordingly, the difference in collision speeds was less than 15 km/h in more than 70 % of 496 evaluated rear-end accidents. v_{coll} values greater than 25 km/h occurred in only 6 % of the cases analyzed (Figure 10).

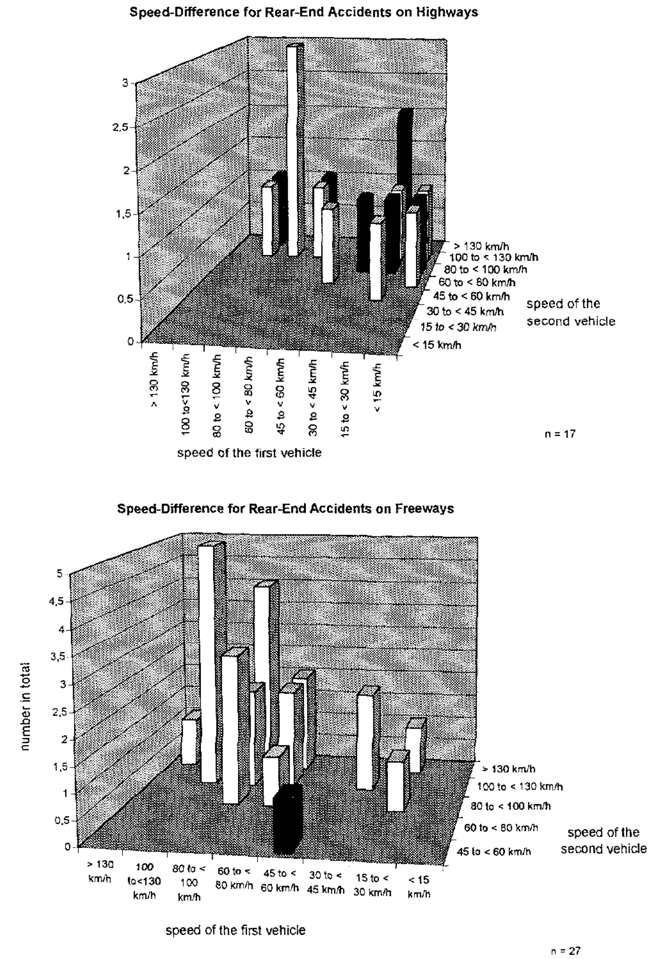


Figure 9. Driving speed differences of passenger cars involved in rear-end accidents on highways and autobahns /4/

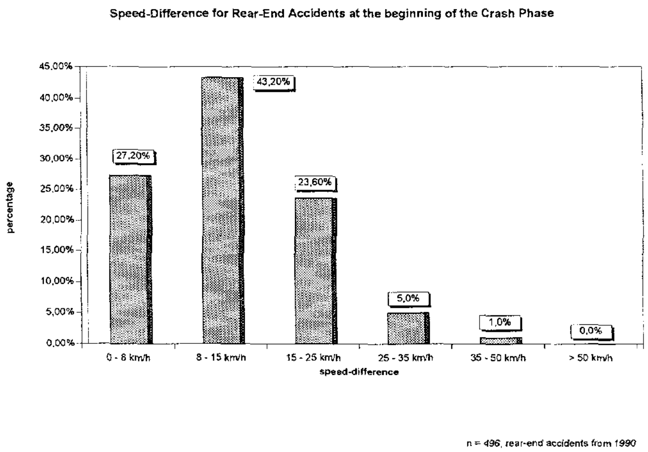


Figure 10. Speed difference at the beginning of the crash phase for rear-end accidents of two passenger cars /5/

Rear-ending stationary and moving vehicles - The number of stationary and moving vehicles involved in rear-end collisions (two-car accidents involving personal injury) are approximately the same. This ratio can be taken as an orientation value for all rear-end collisions irrespective of the location in which they occurred.

Injuries - Approximately half of all persons injured on the autobahn sustain their injuries in rear-end collisions. In 1996 a total of 20,210 persons were injured during rear-end accidents on the autobahn, 316 of whom were killed and 3,330 of whom suffered serious injury. The number of casualties on country roads totals 27,011, of whom 190 were killed and 3,655 were seriously injured. Rear-end collisions thus result in about 16 % of all persons injured on country roads and 50 % of all persons injured on the autobahn (Table 2).

Table 2:
Motorists involved in rear-end accidents - 1996 /3/

Motorists involved in accidents	Urban		Country roads		Autobahn		Total	
	abs.	% total	abs.	% total	abs.	% total	abs.	% total
Minor Injuries	66.838	28,5	23.166	20,8	16168	53,8	106.172	28,2
Severe Injuries	5.627	10,4	3.655	6,9	3.330	37,1	12.612	10,8
Killed	87	4,1	190	3,4	316	3,1	593	6,8
Involved Motorists	72.552	24,9	27.011	15,9	20.210	49,5	119.377	23,8
Rear-end Accidents	55.976	23,7	17.776	15,8	11363	45,6	85115	22,8

Types of rear-end accidents - Zierden /6/ analyzed 24 rear-end accidents and used this to derive a typology of rear-end accidents (Figure 11). The data material used (GDV, 1990) contains rear-end accidents from all locations (city streets, county roads and the autobahn). The following were described as typical situations for rear-end accidents:

1: rear-end accident along a straight road (2 or more persons involved) 57%
2: rear-end accident in junctions (with/without traffic lights) 32 %
3: rear-end accident in curves 11 %

The number of rear-end accidents involving several persons is not insignificant /5, 9/.

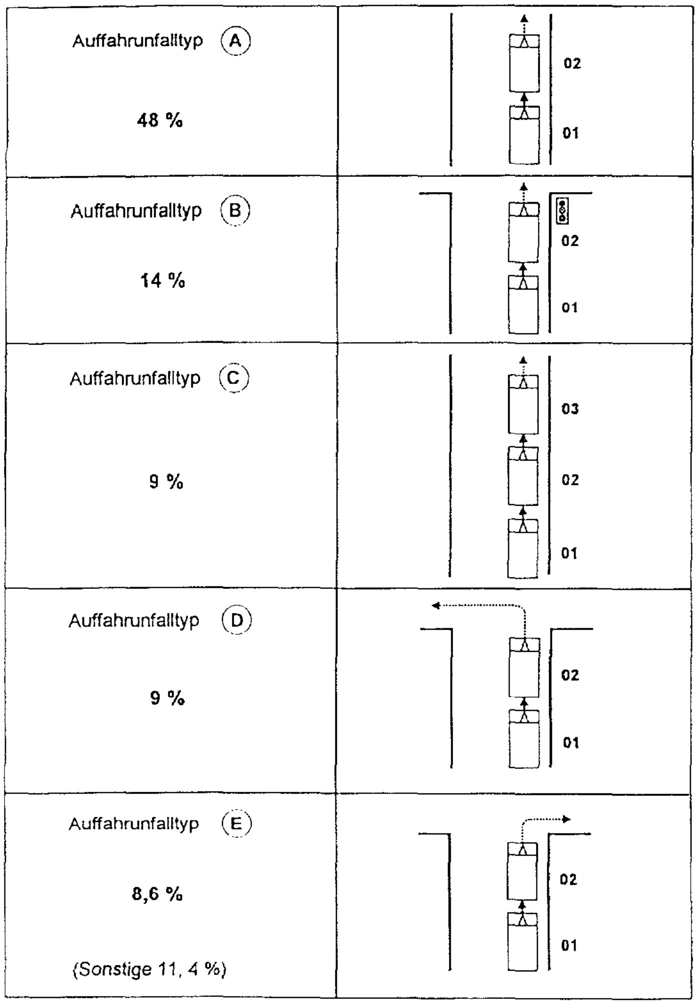


Figure 11. Types of rear-end accidents /6/

Factor Analysis - A number of existing accident databases were used to evaluate parameters for the events leading up to an accident. One method is described below which was used to perform a complex system analysis of a database maintained by the German Insurance Association (GDV) containing 15,000 two-car accidents involving personal injury. Figure 12 shows the mathematical-statistical methods that were used either individually or in the sequence given.

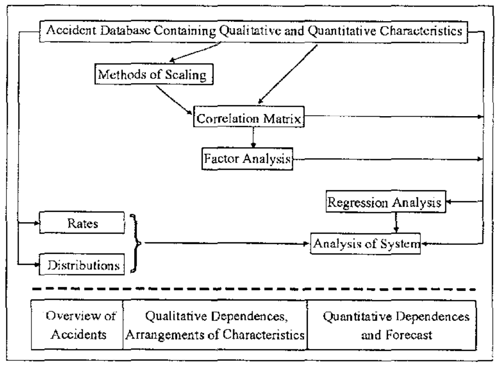


Figure 12. Scheme of accident data analysis

The calculation of frequencies and distributions provides an overview of the individual characteristics. The connections between the accident characteristics are reproduced by the correlation matrix. In order to calculate the correlation coefficients, it is advantageous to assign values to the expressions of the individual characteristics (clear, rain, snow, hail, etc. for the example of weather) when the quantitative characteristics are known (e.g. weather conditions, visibility, etc.). The scaling method according to Bargman/Schünemeyer (1989) was found to be suitable for this purpose.

If there are many characteristics that describe the accident, the connections in the correlation matrix can no longer be interpreted. Factor analysis can then be used for the purpose of interpretation. The aim of factor analysis is to attribute the correlations between the characteristics to the action of common, linearly independent (fictive) factors. To do this, the individual characteristics are represented in a coordinate system based on the calculated correlation matrix in such a way that this reproduces the existing connections as best possible. The axes of the coordinate system are termed "factors". All characteristics are assigned "charges" with respect of each factor. These charges can be interpreted again as correlation coefficients. The difference between the original correlation coefficient and the correlation coefficient reproduced by this procedure is termed the "residual". The term "communality" is understood to mean the automatic correlation that is reproduced for each and every characteristic. It is a measure of the degree to which the deviation of a characteristic can be explained by the factor system found.

Factor analysis methods construct the individual factors one after another in such a way that these factors achieve the best possible reproduction of the existing correlation matrix. Based on this assumption, the first factor will thus have the greatest influence in the entire system.

The coordinate system that is found can be modified by rotating the individual axes without changing the connections between the individual features. Figure 13 is an example of such a rotation for a two-dimensional coordinate system. The connections between characteristics M1 ... M6 cannot be clearly seen with respect to the original system (F1, F2). In the rotated coordinate system (F1', F2'), however, it is obvious that characteristics M1, M4 and M6 are determined substantially by the first factor F1' and characteristics M2 and M5 are determined by the second factor F2'. The charges of the characteristics are very small with respect to the other axis. Only characteristic M3 has large charges with respect to both factors. Hence, the factors can be interpreted on the basis of the characteristics: F1' is explained by characteristics M4 and M6, and F2' is explained by characteristics M2 and M5.

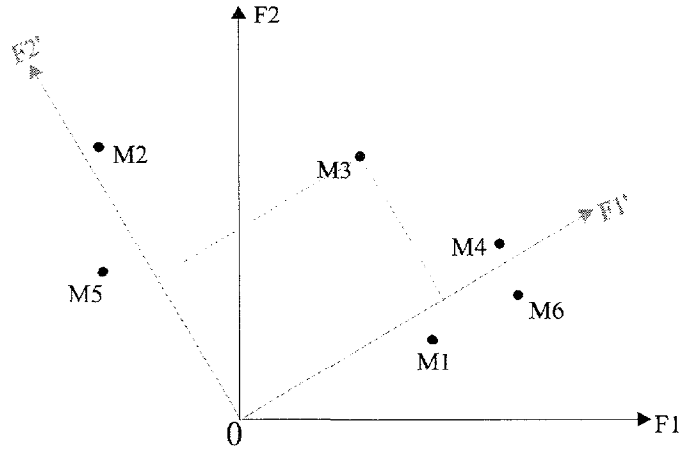


Figure 13. Rotation of the coordinate system

Factor analysis thus makes it possible to:

- define a number of linearly independent factors which represent the common causes of the origin of the characteristics,
- determine the influence each parameter has on each factor,
- ascertain the extent to which the deviation of one parameter can be explained by the others (the "communalities" are a measure of this),
- determine the ranking of the characteristics with respect to a selected target parameter by a special rotation of the factor charges.

When this method is used to evaluate accident data, the problem of the missing values must be given special consideration. This is a problem that occurs frequently (because forms are incompletely filled out; because the starting material makes interpretation impossible, such as an interpretation of the driving speed prior to the collision). This problem can be resolved by not using the correlation matrix itself as the input matrix for the analytical method, but rather by using the matrix of the correlation coefficients that have been calculated for each pair of characteristics. This special point must be taken into account when interpreting the results.

Statistical analysis has been applied to a random sampling of n=3000 accidents. Of these samples, 1,500 cases were selected on the basis of the front-to-rear type collision. The connections between the described accident characteristics were then investigated using the factor analysis procedure. Table 1 shows the rotated factor charges that are discussed below. It is clear that the use of extracted factors 1 to 4 makes fundamental connections between the characteristics obvious. It is of course also possible to expand this procedure to include other factors as well. This, however, in no way improves the validity in this particular case, since the sum of the inherent values of the correlation matrix reproduced on the basis of the factor solution found is greater or equal to the sum of the inherent values of the correlation matrix that is based on the system of characteristics (the condition that will abort the procedure). This means that the factor solutions that have been found can be used to explain at least 95 % of the total variance of the present system of characteristics.

As described above, the factor charges depicted in Table 3 are correlations between the characteristic and the factor, i.e. the factor is determined by the intensity (amount) of the correlation coefficient due to the characteristic (e.g. factor 1 correlates to 0.93 of the total extent of damage 01).

The characteristics, on the other hand, are determined on the basis of their correlations with the factors.
n the present case, factor 1 can be regarded as the factor for the accident sequence (the high correlation with the total extent of damage to both vehicles). Factor 2 represents the vehicle size of the driver causing the accident (output and mass) and factor 3 indicates the vehicle size of the person involved in the accident. Finally, the severity of the injuries and the age of the driver causing the accident predominate in factor 4.

The sex of both drivers, the original registration of the vehicle involved in the accident as well as the age and extent of injury to both drivers could not be explained on the basis of the factor system; the communalities for these characteristics are smaller than the maximum random value of the correlation coefficient which amounts to approx. 0.05 in 1,500 cases (with an error probability of 0.05). This means that the variations of these characteristics cannot be attributed to the other characteristics. They are either independent input parameters for this total system, or they are influenced by other characteristics not yet contained in the system. If the accidents can be described more extensively by supplying additional accident characteristics (in particular those describing the circumstances and sequence of events leading up to the accident), then one can rightly expect to uncover new findings in accident research by using the factor analysis method.

Comparison with the United States - The General Estimates Systems (GES) database contains a representative random sampling of the traffic accidents that have occurred in the United States of America. For the year 1994, there are 13,702 rear-end accidents in all locations contained in the random sampling totaling 55,759 accidents. The random sampling also includes rear-end accidents caused by or involving trucks. Compared with the results for Germany, the following similarities and differences were found with regard to rear-end accidents:

Similarities

- a dominance of male drivers responsible with a high number of young and elderly drivers
- rear-end accidents usually occur on dry pavement (> 70%)
- rear-end accidents frequently occur at good visibility (no rain, fog) - approx. 75%
- drivers responsible frequently drive old vehicles (> 5 years)
- inattentiveness is virtually the sole reason for rear-end accidents
- low collision speeds, 63 % of all U.S. cases occur at less than 32 km/h (= 20 mph)

Differences

- higher proportion of rear-end accidents at junctions and crossings in the U.S. (USA 44 %, Germany 27 % (mean value for country roads and the autobahn))
- more rear-end accidents in daylight in U.S. (USA 79%, Germany 55%)
- based on their share of traffic, luxury vehicles cause fewer rear-end accidents in U.S.; the opposite trend has been found for Germany
- the speed limits are lower in the U.S.: 50 % of all rear-ending vehicles occur while the vehicle is travelling slower than 32 km/h (=20 mph) and 78 % slower than 56 km/h (=35 mph)
- there is a greater number of rear-end accidents involving stationary vehicles in U.S. (86 % in the U.S., about 50 % in Germany)
- there is a greater number of rear-end accidents at junctions with traffic signals in U.S. (26 % USA, 14 % Germany)

Additional findings for the U.S.

- in 72 % of all rear-end accidents, the driver responsible for the accident does not react to prevent the accident; in 11 % of all cases, he attempts to brake
- 90 % of all drivers causing accidents do not suffer injuries
- the influence of alcohol was cited in 3 % of all rear-end accidents

- the airbag activated in 1.4 % of all cases

Table 3:
Factors for the analysis of rear-end- accidents

Characteristic	Factor 1 material damage	Rg Nr	Factor 2 guilty party (gp)	RgNr	Factor 3 Non guilty party (ngp)	RgNr	Factor 4 accident severity	Rg Nr	commu-nalities
Total gp	0,93358	1	-0,18573	5	-0,10308	9	-0,06782	9	0,94991
Total ngp	0,80672	2	-0,19764	4	-0,22532	3	0,01076	13	0,72096
MAIS guilty driver	0,42002	3	0,0999	6	-0,09863	10	0,32505	1	0,27971
Output vehicle 1	-0,12242	6	-0,71879	1	0,13895	5	0,13	6	0,57293
Mass vehicle 1	-0,10722	7	-0,68235	2	0,19279	4	0,17961	4	0,54573
1st Reg.1	-0,10202	8	-0,27499	3	0,10583	8	0,23722	3	0,15045
Output vehicle 2	0,08716	9	0,07107	8	0,63131	1	0,06496	10	0,42214
Mass vehicle 2	0,16691	4	6,98E-03	12	0,59017	2	-0,02734	11	0,37202
Age driver 1	-0,15343	5	0,01163	11	0,07663	12	0,30168	2	0,12546
MAIS driver 2	0,06347	10	0,01499	10	-0,07617	13	0,1434	5	0,03134
Age driver 2	4,76E-03	12	-0,07148	7	0,13354	6	0,06811	8	0,02788
1st Reg. vehic-le 2	0,01156	11	0,02862	9	0,11802	7	0,01842	12	0,01522
Gender driver 1	1,16E-03	14	2,05E-03	13	-0,0777	11	-4,71E-03	14	6,06E-03
Gender driver 2	-1,50E-03	13	-1,47E-03	14	0,03758	14	0,08747	7	0,01016
Residuals:									
mean value:	5,44E-04		3,57E-04		1,98E-04		1,70E-04		
Minimum:	2,08E-04		3,69E-04		6,99E-04		1,19E-06		
Maximum:	0,54712		0,33685		0,08561		0,06419		

The differences shown above can be explained by, among other things, the difference in traffic conditions and the difference in driving behavior in both countries. The above-mentioned differences should also be taken into consideration when using the accident data.

ACCIDENT AVOIDANCE AND SAFETY BENEFITS

The safety benefits that can be achieved by putting the AAC system on the market can only be estimated, since there are no past figures available on the number of cars equipped, no past information on the system properties of the standard product nor any practical experience, among other things.

Assuming that

- it is not possible to detect stationary objects
- that speeds exceed 40 km/h
- that all cars (100 %) are equipped with an AAC system
- that the system functions properly

first generation ACC systems would influence the outcome of approximately 40 % of all car to car rear-end accidents on country roads and 60 % on the autobahn.

Even if the focal point of rear end crashes with personal injuries is characterized by a crash into a stopping car or a car with a speed lower than 40 kph, the number of crashes which might be influenced by AAC is considerable:

autobahn	- approx. 7,000 rear-end accidents involving personal injury and about 12,000 persons involved in accidents (= approx. 27 % of all autobahn accidents involving personal injury) - approx. 2,000 rear-end accidents involving severe material damage (= approx. 12 % of all autobahn accidents in this category) - approx. 20,000 rear-end accidents involving minor material damage (= approx. 12 % of all autobahn accidents in this category) - reduction in accident costs by approx. 440 million Deutschmarks
country road	- approx. 7,100 rear-end accidents involving personal injury and 11,000 persons involved in accidents (= approx. 6 % of all accidents involving personal injury on country roads) - approx. 1,100 rear-end accidents involving severe material damage (= approx. 3 % of all accidents in this category on country roads) - approx. 11,000 rear-end accidents involving minor material damage (= approx. 3 % of all autobahn accidents in this category) - reduction in accident costs by approx. 350 million Deutschmarks

The cost volume was estimated using recognized cost records (Deffke et al, 1995). Zierden (1997) cites a value of 36,000 Deutschmarks as an orientation value for the average amount of damage in rear-end accidents involving personal injury. This value contains an amount of 17,000 Deutschmarks for material damage and 19,000 Deutschmarks for personal injury and has been calculated from rear-end accidents in all road classes. The comparatively low average is explained by the low subsequent damage in the case of rear-end accidents.

In view of the fact that in the foreseeable future only a small number of vehicles will be equipped with the ACC system (only newly registered cars) and bearing in mind that there is only a limited possibility of avoiding rear-end collisions, it can justifiably said that the practical impact of first generation of ACC systems will be lower by a factor of 10. This would then mean that the first generation ACC system will influence the outcome of less than 2 % of all autobahn accidents and less than 0.3 % of all accidents occurring on country roads.

These percentages are very low, although the safety benefits to persons involved in accidents and potential material damage must not be overlooked. If 10 % of all cars were equipped and the above-mentioned assumptions are applicable, then the safety benefits (per year) would still amount to about 2,300 persons involved in accidents and approximately 80 million Deutschmarks.

SYSTEM REQUIREMENTS AND OUTLOOK

Traffic safety can be improved by developing new technologies. As becomes clear using the ACC system as an example, such systems must be highly efficient to make their influence felt in traffic accidents. In the case of the ACC system, it appears imperative to make detection of stationary and slowly traveling vehicles possible, to enhance the efficiency of the system and to extend its field of application to country roads and streets within city limits.

Since drivers cause rear-end accidents as a rule out of inattentiveness and since the regulatory process is subject to comparatively simple marginal conditions, the development of the ACC system is basically promising for situations involving rear-end accidents. More details about the speeds in rear-end accidents and the follow-up costs of the accidents are necessary in order to be able to more exactly differentiate costs and benefits.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Hans Bäumler, Mr. G. Scheibe, Mr. M. Zierden and Mr. J. Winkler for their contributions to this study. A special thank is due to the Accident Prevention Committee of the German Motor Insurers for the financial support of this study.

REFERENCES

/1/ HUK-Verband: "Vehicle Safety 90", HUK-Verband, Institute for Vehicle Safety, Munich, 1994

/2/ Langwieder, K., Sporner A., Hell W.: "Struktur der Unfälle mit Getöteten auf Autobahnen in Bayern im Jahr 1991, HUK-Verband, Institute for Vehicle Safety, Munich 1994

/3/ Statistisches Bundesamt."Straßenverkehrsunfälle 1996", Fachseite 8, Reihe 7, Herausgeber Statistisches Bundesamt, Wiesbaden, 1997

/4/ Bach, E.; Scheibe G.: "Unfallvermeidung und Wirkungsmöglichkeiten von Fahrerassistenzsystemen (Aktive Sicherheit)". Forschungsbericht Institut Fahrzeugtechnik der HTW Dresden, 1998

/5/ Eichberger, A.:" Beschleunigungsverletzungen der Halswirbelsäule bei Pkw/Pkw-Heckkollisionen im realen Unfallgeschehen". Diplomarbeit TU Graz, 1995

/6/ Zierden M. "Charakteristik der Unfallsituationen bei Auffahrunfällen mit Personenschaden". Diplomarbeit HTW Dresden, 1998

/7/ Deffke, Ernst, Köppel, Meewes: "Kostensätze für die volkswirtschaftliche Bewertung von Straßenverkehrsunfällen - Preisstand 1995". In: Straße und Autobahn, Heft 1, S.24, 1995

/8/ Hartung, J. und Elpelt B: Multivariate Statistik. 3. Auflage; München, Wien: Oldenburg, 1989

/9/ Tschöpe, Cl.: "Analyse von Unfällen junger Fahrer hinsichtlich der Kollissionsabläufe und mitwirkender Faktoren bei der Enstehung der Krisenssituation". Diplomarbeit GH Wuppertal, 1997

/10/ Winkler J.:"Pkw mit Anti Blockier Systemen im realen Unfallgeschehen". Diplomarbeit FH München, 1996