Accident Involvement of Motorcycles – Description of the Current Situation in Germany Using Data from Federal Statistics and In-Depth-Studies

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Abstract – It is well known that motorcycle riding is fascinating but quite more dangerous than for example car driving. In 2006, 5,091 persons were killed as victims of crashes occurring on public roads in Germany. 52% (2,683) were car occupants, 16% (793) motorcycle riders, 14% (711) pedestrians, 10% (486) bicycle riders, 5% (235) commercial vehicle occupants, 2% (107) riders of smaller powered two-wheelers, called "Mofa, Moped and Mokick". This shows that motorcycle riders recently are the second largest group of killed traffic participants in Germany.

Latest information coming from the Federal Statistics predict for the year 2007 the figure of 4,958 killed road victims in total [1]. This would be again a successful reduction (-133 killed persons or –2.6% compared to the year 2006). But the news coming from the Federal Statistics during the year 2007 and at the begin of 2008 did not always tell the same positive story. It is questioned whether the positive trend of substantially reduced figures of killed road user year by year will longer continue for Germany. That means it could be impossible to reach the ambitious target, set by the European Commission, to cut in half the figure of killed road users until the year 2010 – compared to the figure for the year 2001.

It was reported that the group of 45 to 49 years old traffic participants (all traffic modes) is conspicuous with an increase of 30% up to 297 killed road users in total from January to August 2007. This increase can be ascribed in particular by an increase of killed motorcycle riders within this age group. Due to mild weather conditions in Germany in 2007 the season for motorcycle riding began relatively early and this may be a main reason for the increase of the figure of killed motorcycle riders by 16% from January to August 2007 [2].

With this background the accident occurrence of motorcycles became more and more essential. As part of the actual discussion about historical trends, recent emphases, causes and relevant structures of the events of motorcycle crashes it is evident, to have latest and carefully updated figures coming from both the Federal Statistics and In-depth studies. The paper will give a contribution to this using the German Federal Statistics and in-depth studies, for example GIDAS. Additional data coming from the DEKRA Motorcycle Accident Database as well as from literature are considered, too. The paper will help to describe the current situation of the accident involvement of motorcycles in Germany.

1 INTRODUCTION

Motorcycle riding on the one hand is fascinating and associated with pleasant experiences. On the other hand, the motorcycle rider is exposed to high accident risks. Out of 5,091 persons killed in traffic accidents in the year 2006 in Germany 793 (16%) were motorcycle riders. The most frequent group of killed crash victims are clearly the car occupants (2,683 fatalities, 52% of all crash victims). But the killed motorcycle riders recently follow as the second largest group. On rank 3 are the pedestrians (711 fatalities, 14%), followed by the bicyclists (486 fatalities, 10%), the occupants of commercial vehicles (235 fatalities, 5%) and the riders of Mofas, Mopeds and Mokicks (107 fatalities, 2%).

Latest provisional figures for the year 2007 show that the figure of killed motorcycle riders in Germany compared to the year 2006 rose by 36 (+4.5%) up to 829. For the same time period the figure of all traffic participants was reduced by 133 (-2.6%) to 4,958. With these figures the share of the killed motorcycle riders increased up to 17%. Whilst the figure of killed pedestrians was reduced by 18 (-2.5%) down to 693, their share of all road victims for the year 2007 remained constant (14%).

Not only against the background of the ambitious target set by the European Commission to cut in half the figure of killed road victims until the year 2010 (based on the 2001 figures), the motorcycle comes into the focus of operational and strategic considerations for further improvements of road safety. In contrast to the decreasing absolute figures of road victims which are striven in general and also realized during the years up to now (despite increasing figures for road users and miles travelled), the motorcycle is peculiar.

The assessment of the absolute figures and their relations must be based, amongst others, on careful analyses considering the registration figures for the fleet as well as for the mileage. Within the framework of ongoing developments and measures for the improvement of the safety of motorcycle riders the key aspects of the accident occurrence and the resulting potentials have to be taken into account. At this juncture it is of importance to judge recent trends also against the background of the historical evolution. Coevally permanent actualisations of the tabulations are necessary to recognise short-term changes, as the case may be.

The paper on hand will give a contribution to this matter. The data source used is predominantly the Federal German Statistics. It starts with a presentation of the historical development that is still remarkable. The recording of the long-term series reaches up to the data of the year 2006, which are recently available in all details. The current situation is also described using data from the official statistics. Supplementary insights into the accident occurrence of motorcycles are given using data and information coming from in-depth-studies and associated databases.

2 HISTORICAL DEVELOPMENTS

2.1 Vehicle-fleet

With the analyses and assessment of the accident participation of certain vehicles and vehicle groups it is functional, to put into account the vehicle-fleet population and the related mileages travelled. In general, the development of the vehicle-fleet population also can be seen in the involvement of the traffic accidents.

Given by the German Federal Motor Transport Authority, the so called “Kraftfahrtbundesamt” (KBA), the vehicle group of motorcycles which is mainly concerned with this article (that are motorcycles bearing an official registration number), contains light motorcycles (so called “Leichtkrafträder”), motorcycles, motor scooters and three-wheeled motorized vehicles, including light four-wheeled motorized vehicles. To simplify, even in official texts or statistics, often only the term “motorcycles” is used for this vehicle group. Some of the associated terms of definitions have changed several times during the last decades. Current definitions and associated driving licenses are shown with Table 1 [3].

The historical progression of the figures of theses vehicles within the time period from 1953 to 2008 is displayed with Figure 1. During the 1950ies the motorcycle was a vehicle used very often for daily participation on the individual motorized road traffic. The vehicle-fleet population of motorcycles and motor scooters reached a first maximum at 2.5 billion vehicles in the year 1956.

Afterwards, the motorcycles as means of mass transport have been substituted by cars rapidly. This resulted in a considerable reduction of the motorcycle fleet until the year 1969 down to almost a tenth (263,486). For the year 1970 the official statistics show for the first time separated figures of registered motorized two-wheelers bearing an official registration number: 141,047 motorcycles, 87,557 motor scooters and as a new sub group 150,000 light motorcycles.

During the 1970ies the motorcycle has been recovered as an individual motorized means of transportation. For under 18-years old people – according to their driving licence – the light motorcycle was still a vehicle for daily use during the entire year. But older traffic participants did not depend on the motorcycle and used it increasingly as an additional vehicle during their leisure times. Motor scooters played a very ancillary role in these years. In the year 1986 with 986,304 motorcycles, 56,895 motor scooters and 361,515 light motorcycles (1.4 billion vehicles in total) a new relative maximum of the fleet population was reached. However, this was far beneath the corresponding maximum of the 1950ies.

Subsequently the fleet population remained more or less constant until the year 1989. Already in the old German countries (figures until 1991) and later on also in the reunified Germany the figures of registered motorcycles again continuously increased. The old all-time high of 2.5 billion motorcycles was reached in the year 1997 (2,243,813 motorcycles, 152,222 motor scooters and 320,745 light motorcycles). This growth continued also for the following years.

Table 1. Sub groups of motorcycles bearing an official registration number and appropriated driving licenses (Source: KBA [3])

Type of vehicle	**Terms of technical regulations**	**Class of driving license**	**Minimal age of driver**
Light motorcycle	2-wheeler up to 125 cm³ up to 80 km/h up to 11 kW	A1 (former 1b) alternatively 1, 1a or 2, 3 or 4 if certificated before April 01, 1980	16 years
Light motorcycle	2-wheeler up to 125 cm³ no speed limit up to 11 kW	A1 (former 1b) alternatively 1, 1a or 2,3 or 4 if certificated before April 01, 1980	18 years
Motorcycle and motor scooter	2-wheeler (also with side car) up to 25 kW up to 0,16 kW/kg	A (former 1a) alternatively 1	18 years
Motorcycle and motor scooter	2-wheeler (also with side car) more than 50 cm³ more than 45 km/h (during the first 2 years: up to 25 kW up to 0,16 kW/kg)	A (former 1) since April 1, 1988 2 years driving licence class A (before 1a) and a minimum of 4.000 km driving experience, if the candidate is younger than 25 years old	20 years
3-wheeled light motorcycles and 4-wheeled motorized light vehicles	3-wheeler, 4-wheeler up to 50 ccm, up to 45 km/h up to 4 kW up to 350 kg	S (since February 1, 2005)	16 years

For the last time in the year 2001 separated figures for registered motorcycles (2,650,749), motor scooters (161,084) and light motorcycles (597,904) are published with the official statistics. For the following years up to 2005 only the sum of motorcycles and motor scooters is displayed. Since 2006, also the figure of registered light motorcycles is included into this sum. Starting with the year 2002, separated figures for three-wheelers and light four-wheelers are reported in the official statistics within the subgroups for motorcycles, too.

For the reference date January 1st, 2007 the Federal Statistics gives the total number of 3,969,103 registered motorcycles bearing an official licence number. This contains 3,885,572 two-wheeled motor vehicles, 6,280 three-wheeled motor vehicles and 77,251 light four-wheeled motor vehicles.

Up to the year 2007, the figures for the vehicle-fleet population did also contain vehicles that have been temporarily out of registration. This has changed with the new simplified vehicle registration procedures. Starting on March 1st, 2007 also the temporarily decommissioned vehicles (approx. 12%) are treated in the same way as the final shut-downs. Consequently, the fleet population reported with the German Federal Statistics contain only vehicles which participate in the traffic flow [4]. This has to be kept in mind for further updates and interpretation of this statistics.

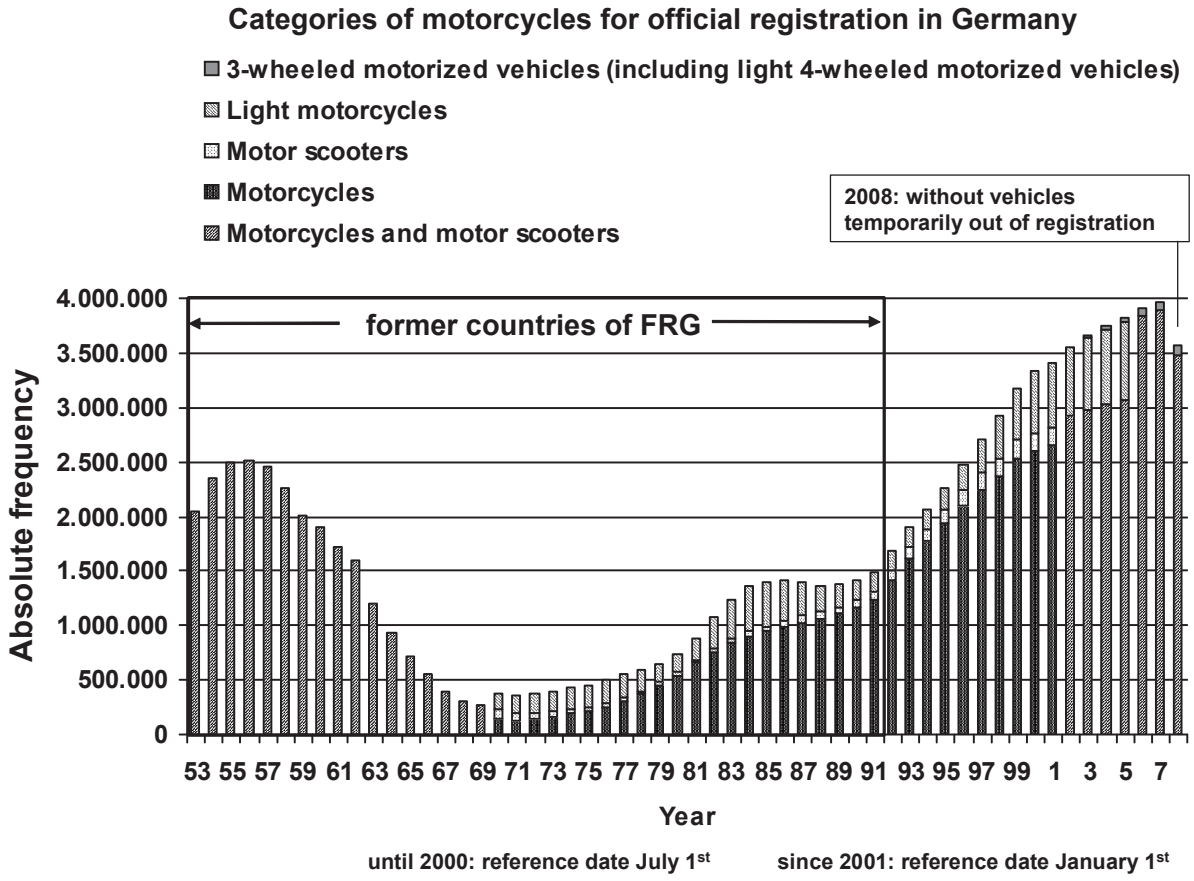

Figure 1: Historical time series of the figures for vehicle-fleet population of motorcycles bearing an official registration number in Germany (years 1953 to 2008; Sources: KBA, StBA)

2.2 Killed motorcycle riders

To analyse historical trends and developments of traffic accidents in Germany, a very useful data source is the series 8 traffic, part 7 traffic accidents, published by the Federal Institute for Statistics (Statistisches Bundesamt, StBA), [5]. Herein and with the annual volumes of the corresponding former series the long-term statistical series for the Federal Republic of Germany began with the year 1953. In the federal accident statistics the motorized vehicles dealt in this paper are defined corresponding to their kind of involvement in road traffic as motorcycles. These are powered two-wheelers bearing an official registration number wherein according to the current definitions contain: Light motorcycles, motor scooters and motorcycles and as well the compulsory approval three-wheelers (including light four-wheelers). Up to now the annual volumes available report until the Year 2006 [6]. Figure 2 illustrates the historical progression of the annual figures of killed riders of motorcycles bearing an official registration number inside and outside urban area compared to the development of the corresponding vehicle-fleet population.

It is noticeable, that up to the 1980ies the figures of the accident victims did follow more or less the figures of registered motorcycles. 4,135 killed motorcycle riders have been reported for the year 1954 with 1,965 fatalities inside and 2,170 fatalities outside urban area. Up recent years this was the absolute all-time high. Until the begin of the 1980ies corresponding to the figures of registered motorcycles subsequently the figures of killed motorcycle riders firstly decreased and then increased again. This can be seen in particular for fatalities outside urban area. A new relative maximum of these figures was then reached in 1982. For this year, 1,453 killed riders of motorcycles bearing an official registration number are reported (959 rural and 494 urban).

For the follow-up years a total decoupling of the figure of killed motorcycle riders from the figure of motorcycles registered occurred. Still in the former countries of the Federal Republic of Germany the

figures of fatalities declined rural and urban, while the figures of registered motorcycles inclined or reminded more or less constant. After the German reunification the figure of killed motorcycle riders was again more or less constant inside and outside urban area until the year 2003. Afterwards, this figure continued to decrease rural but remained roughly constant urban.

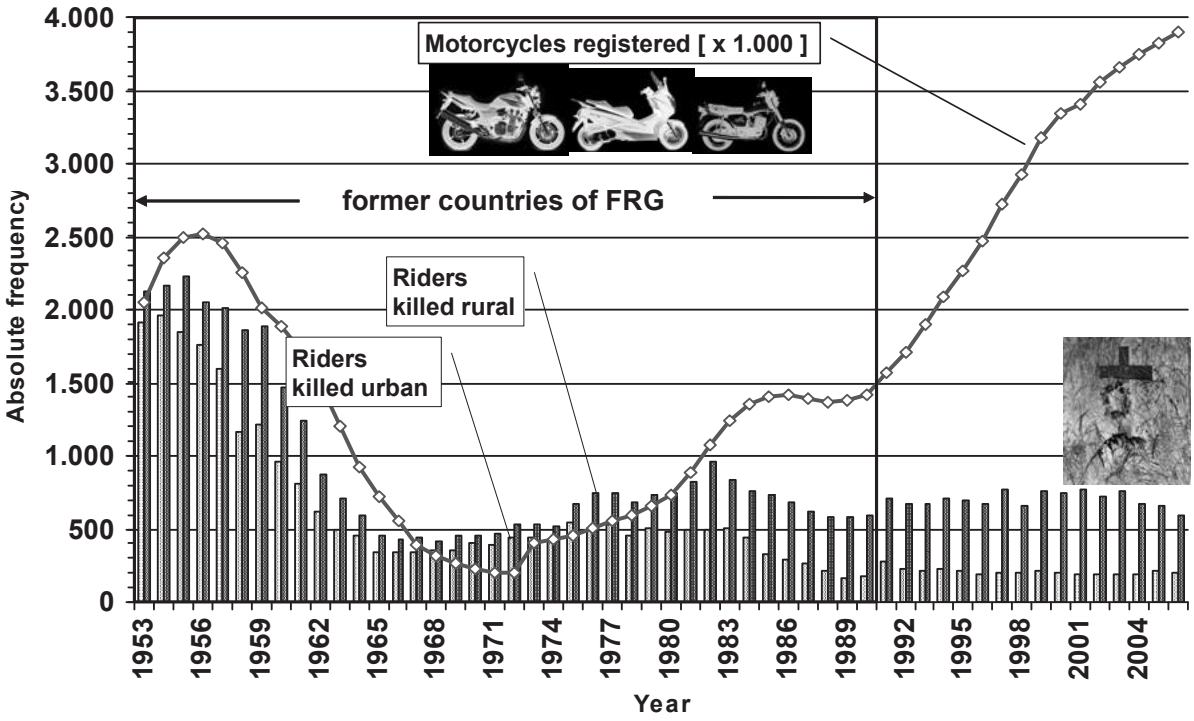

Figure 2: Historical time series of the figures of killed users of motorcycles bearing an official registration number in Germany from 1953 to 2006, subdivided by the locality of the accident (rural, urban) and compared to the corresponding vehicle-fleet population (Source: StBA)

With the interpretation of the accident figures of motorcycles there is a consistently remark to the weather conditions. Thereby motorcycle riders do not participate more often in accidents due to dirty weather. Quite the contrary: The better the weather, the more motorcyclists are en route and are endangered by the daily risks of road traffic. For example in the year 2004 the figure of fatal injured occupants of motorcycles bearing an official registration number declined considerably from 946 in the previous year 2003 by 88 (-9%) down to 858. As one of the reasons the comment to the official statistics mentioned weather conditions: During the summer of 2004 in Germany the weather was clearly less convenient than in the so called “summer of the century” of 2003 [7].

For the year 2006 the statistics report 793 killed motorcycle riders. 592 of them died in rural crashes and 201 urban.

From the monthly report of December 2007 it can be seen that in the entire year 2007 in total 829 drivers of motorcycles bearing an official registration number have been killed, 162 urban and 667 rural (these are preliminary figures). That points out a decrease of the figure of killed occupants of motorcycles bearing an official registration number, compared to the previous year, by 39 (19%) inside urban area. But outside urban area the corresponding figure increased by 75 (13%). In total the figure of killed motorcycle riders increased by 36 (4.5%). As one of the reasons it is mentioned, that in spring 2007 mild weather conditions began relatively early and caused by this the season for motorcycle riding did also start earlier.

As in previous years, also for the year 2007 the statistical figures which are available show considerably more fatal accidents of the motorcycles bearing an official registration number outside then inside urban area. This is an indication for the exceeding risk on rural accidents, which can be explained by the higher speeds normally driven by the traffic participants who are on the roads outside urban area.

2.3 Risks related to the vehicle-fleet population

One of the possible exposure data to indicate the accident risks of traffic participants is the relation between drivers and passengers and the corresponding vehicle-fleet population. On this, Figure 3 illustrates the figure of killed drivers and passengers of motorcycles bearing an official licence number per 100,000 of these vehicles registered in the fleet-population for the years 1953 to 2006. For the purpose of comparison the according courses of these risk figures for the riders of motorised two-wheelers bearing an identification mark (Mofa, Moped and Mokick) and for the occupants of cars are depicted, too. Caused by the definitions of the groups of traffic participants within the Federal Statistics the figures for Mofa, Moped and Mokick are first available in 1955 and for cars in 1957.

In the year 1957, for example, 89 drivers and passengers in cars, 68 riders of Mofas, Mopeds and Mokicks, and 149 occupants of motorcycles bearing an official registration number have been killed in traffic accidents per 100,000 of the corresponding vehicles registered in the fleet. The courses of the curves during the decades show a general trend to a steady and sustainable improvement of the safety of vehicles and traffic for the cars and for the smaller motorcycles without official registration. This was really not the case for the motorcycles bearing an official registration number within the time period from 1963 to 1969. For these vehicles the risk coefficient which is shown here was tripled from 100 for the year 1963 up to 308 for the year 1969. In the year 1969 a first success in breaking this fatal trend occurred. During these years an intensive debate happened on the mandatory wearing of protection helmets for motorcycle riders. Many motorcycle riders used the helmet already on a voluntary basis. The legal obligation of wearing a helmet for riders of motorcycles having a maximum speed of more than 40 km/h (without fine) was on January 1st, 1976. With this date, a sustainable trend to the reduction of the risk of a motorcycle rider to be killed in an accident began. It is remarkable, that the follow-up tightening with fines did not significantly enhance this already positive trend.

The steady and sustainable reduction of the risk of being killed for drivers and passengers of motorcycles bearing on official registration number was then also evident (as already before for the riders of Mofas, Mopeds and Mokicks as well as for the occupants in cars). These trends are still valid until recent years. Short-term increases did occur directly after the German reunification. But this have been only temporary events and also some irregularities during the consolidation of the statistics for the old and new countries could have been one of the related reasons.

Also in the reunified Germany the risk based on the vehicle-fleet populations to be killed in a traffic accident declined further on until today for the groups of traffic participation discussed herein. In particular the long-term evolutions show, that the corresponding curves decline more and more asymptotically flat during the last years. In other words: The marginal utility for further improvements of vehicle and traffic safety has gone smaller and smaller in the recent past.

For the improvements of traffic and vehicle safety seen here, amongst the causes are measures related to the vehicle technique, enhancements of the protection clothing for motorcycle riders, accompanying legal measures, progress in rescue services during first aid and medical care at the scene, transport and medical treatment for accident victims in a hospital, a general enhancement of the sense of responsibility and safety within the mobile population, and last but not least measures to improve road infrastructure. As mentioned before, in the course of time during the previous decades a considerably saturation took place. In only extrapolating the historical trends further improvements may be no longer expected. But this could be changed, whether fundamental new safety technologies with high efficiency, for example in the area of primary (active) safety to avoid accidents, could be made accessible.

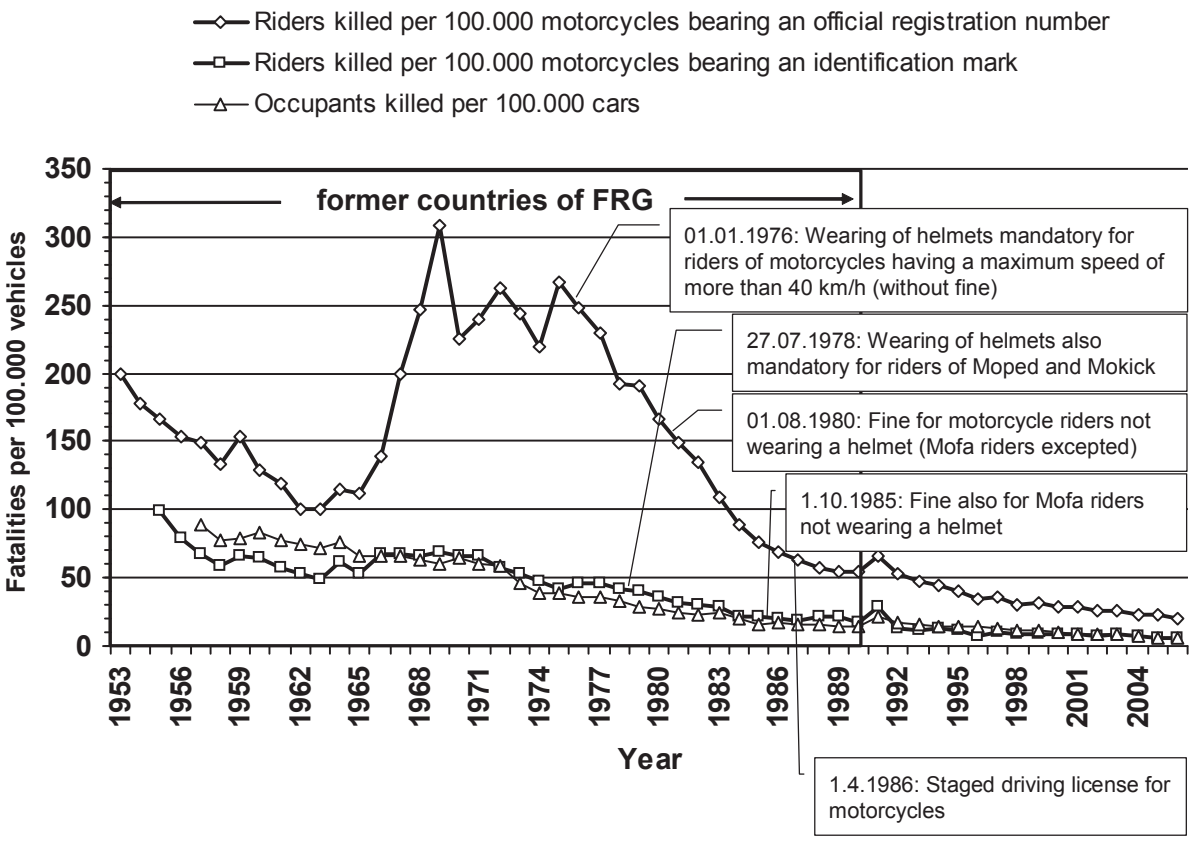

Figure 3: Killed occupants of motorcycles bearing an official licence number, of motorcycles bearing an identification mark (Mofa, Moped, Mokick) und in cars, each related to 100,000 corresponding vehicles in the fleet-population in Germany from 1953 to 2006 and corresponding legal measures (Sources: StBA, KBA)

20 occupants of motorcycles bearing an official registration number have been killed in traffic accidents per 100,000 of these vehicles in the fleet population in the year 2006. Compared to the corresponding risk-index of 308 for the year 1969 this is equivalent to a tremendous reduction of 208 (94%). Nevertheless, the risk of being killed in an accident based on the number of vehicles registered in the fleet population is considerably higher for motorcycle riders than for riders of Mofas, Mopeds and Mockicks and for car occupants. For these two vehicle groups in the year 2006 one can calculate in each case 6 fatalities per 100,000 vehicles. Compared to this figure the corresponding risk of motorcycle riders (20) is more than three times larger.

2.4 Miles travelled

Another reference to calculate the accident risks of a certain road-user group are their miles travelled. A cause of an increase or decrease of the risk based on the vehicle population may be an altering in the mileage corresponding to the duration of active traffic participation.

From the Federal Statistics data for the mileages of several vehicle groups are only available in sub ranges. Amendatory information is given by the German institute for economic research (Deutsches Institut für Wirtschaftsforschung, DIW) using a model-based calculation for different kinds of motorized vehicles [8]. With regard to the vehicle groups shown with Figure 3, Figure 4 illustrates the so called “native mileages” per vehicle (including vehicles temporarily out of registration) and per year for the time period 1953 to 2006. “Native mileage” means the driven distance of vehicles which are registered in Germany on roads inside and outside of Germany.

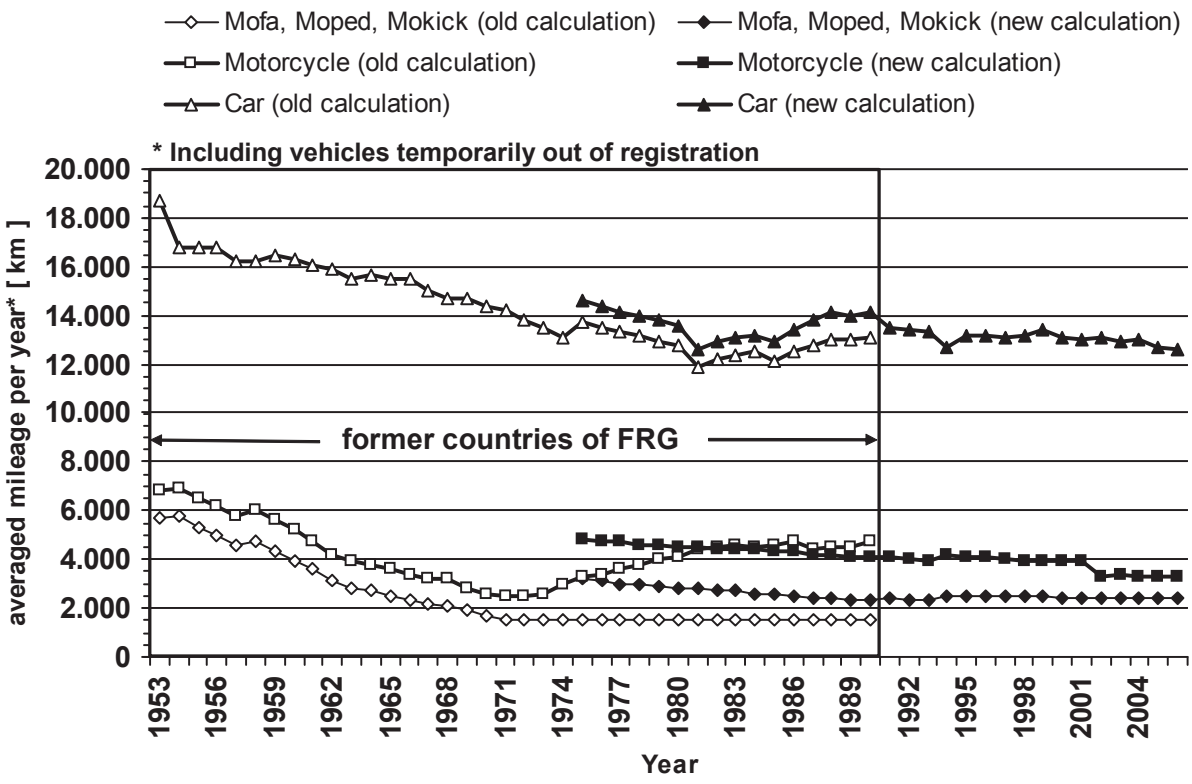

Figure 4: Mean value of the native annually mileages for Mofas, Mopeds und Mokicks (motorized two-wheelers bearing an identification mark), for motorcycles bearing an official registration number and for cars for the time period 1953 to 2006 (Source: DIW)

The calculated values are results from a model-based computation which is predicated on the total fuel consumption in Germany. Amongst others the vehicle-fleet population and the fuel consumption of different vehicle groups are taken as parameters for the model. Using the results of collections of real-world data for mileages and economics the results of the model-based computations are adjusted from time to time [9]. This is then also done for some of the years prior to the adjustment. Compared to cars with this procedure it is possible that for the motorized two-wheelers with its smaller mileages a relatively large variance of actualised mileages per vehicle and year is the result of such an update (see results of old and new calculation in Figure 4). This is the reason why for historical long-term illustrations of the course of risks based on the mileage of motorized two-wheelers these values seem to be suboptimal.

But it is evident, that till the begin of the 1970ies the mileages per vehicle and year for the several vehicle groups have been reduced. In principle this is convenient for the risks calculated on the basis of the vehicle-fleet only, because the vehicles do less participate in the road traffic and therefore they are fewer endangered by the corresponding accident risk.

The drastic growth of the fatality risk for motorcyclists based on the figure of registered vehicles only from 1963 to 1969 (see Figure 3) is not explainable by the course of their miles travelled, indeed. For the relevant time period the mileage of these vehicles did not increase, quite the contrary it decreased!

For the following years the results of the model-based calculation of miles travelled per vehicle and year show a slightly downwards drift, whereas for some years also constant mileages can be seen. Hence, the relative course of the fatality risk based on the figures of registered vehicles also shows roughly the relative course of the risk which is based on the mileage.

However, when considering the mileage, the absolute fatality risk of motorcycle riders is significantly higher because of their smaller distances travelled per year compared to cars. In Table 2, an overview on this matter is given for the years 1957, 1970, 1991 and 2006.

Table 2: Killed occupants of motorcycles bearing an official registration number, of motorcycles bearing an identification mark (Mofa, Moped, Mockick) and of cars, related to their vehicle-population and to their miles travelled in total per year (Sources: StBA, KBA, DIW)

Year		**1957**	**1970**	**1991**	**2006**
motorcycles bearing an official registration number	Killed drivers and passengers	3,604	853	992	793
	Vehicle population	2,419,000	378,604	1,491,694	3,902,512
	Mileage in total per year	14.1 billion km	0.6 billion. km	8.7 billion. km	13.2 billion km
	Killed per 100,000 vehicles	**149**	**225**	**67**	**20**
	Killed per 1 billion vehicle kilometres	**256**	**1.422**	**114**	**60**
motorcycles bearing an identification mark (Mofa, Moped, Mokick)	Killed drivers and passenger	1,116	700	243	107
	Vehicle population	1,650.000	1,052,543	867,875	1,793,209
	Mileage in total per year	7.6 billion km	2.0 billion km	4.9 billion km	4.6 billion km
	Killed per 100,000 vehicles	**68**	**67**	**28**	**6**
	Killed per 1 billion vehicle kilometres	**147**	**350**	**50**	**23**
Car	Killed drivers and passenger	2,293	8,989	6,801	2,683
	Vehicle population	2.583.656	13.941.079	32.087.560	45.668.108
	Mileage in total per year	41.3 billion km	201.1 billion km	496.4 billion km	586.3 billion km
	Killed per 100,000 vehicles	**89**	**65**	**21**	**6**
	Killed per 1 billion vehicle kilometres	**56**	**45**	**14**	**5**

Here too, for the cars a continuous and sustainable reduction of the risk from 56 occupants killed per 1 billion kilometres in the year 1957 to corresponding 5 occupants killed in the year 2006 is evident. For motorcycles bearing an identification mark (Mofas, Mopeds and Mokicks), caused by a reduction of the mileage with a roughly constant figure of 68 respectively 67 riders killed per 100,000 vehicles initially there was an increase from 147 riders killed per 1 billion kilometres in the year 1957 to corresponding 350 persons killed in the year 1970. Subsequently this was followed by a clear reduction down to accordingly 50 fatalities in the year 1991. In the year 2006 for this vehicle group the risk is calculated to 23 occupants killed per 1 billion kilometres.

For the drivers and passengers of motorcycles bearing an official registration number the risk ratio is 256 fatalities per 1 billion kilometres travelled in the year 1957. The year 1970 shows with

corresponding 1,422 fatalities an extreme risk-ratio which is 4.6 times higher. For the year 2006 recently 60 drivers and passengers of motorcycles bearing an official registration number have been killed per 1 billion kilometres. Hence, related to the mileages in the year 2006 the risk of being killed in a traffic accident for the riders of motorcycles bearing an official licence number is 12-times higher than for car occupants and 2.6-times higher than for the riders of Mofas, Mopeds and Mokicks.

One main reason for the increased risk-ratios for riders of motorcycles bearing an official registration number per vehicle both regarding the fleet population and regarding the mileage travelled compared to that risk-ratio for car occupants surely is that the motorcycle rider is not protected by a surrounding safety cell which protects the occupants of cars combined with the protective effects of restraint systems and padding. Compared to Mofas, Mopeds and Mopeds the increased risk ratios for motorcycles bearing an official registration number can be mainly explained by the higher speeds of the motorcycles (and also of other traffic participants), especially on roads outside urban area.

In the year 2006 inside urban area 55 riders of Mofas, Mopeds and Mokicks have been killed in an accident. Outside urban area the corresponding figure of fatalities with 52 was nearly the same. For the motorcycle riders the figure of killed riders inside urban area was 201 and the corresponding figure of occupants killed in accidents outside urban area was 592, that means almost 3-times greater. One of the possible explanations is, that for motorcycles the distance travelled on rural roads is greater than that for Mofas, Mopeds and Mokicks. But there are no confirmed data available to verify this. On the other hand, in general the risk of being killed in an accident outside urban area increases with the speed especially for the so called “unprotected road users”. It is obvious that the protection clothing (helmet, overall, gloves, boots) normally used by the motorcycle riders is not sufficient to compensate this higher risk for appropriate severe impacts.

2.5 Shares of killed, severely injured and slightly injured motorcycle riders

In terms of the progression of the injury severity of the drivers and passengers of motorcycles bearing an official registration number the alterations of the shares of slightly injured, severely injured and fatally injured persons give revealing indications. This is displayed for the time period from 1953 to 2006 with Figure 6.

In 1953, in total 125,043 drivers and passengers of motorcycles bearing an official registration number have been victims of a traffic accident. Hereof 3.2% (4,046) have been killed, 39.0% (48,828) have been severely injured and 57.7% (72,169) slightly injured. During the following decades these shares did change only little. For the year 2006 the share of killed motorcycle riders was 2.4% (793 of 34,221 corresponding victims in total) and the share of severely injured was 32% (10,590). This is clearly different for example to the accordingly development for pedestrians involved in traffic accidents. For these pedestrians the share of killed and severely injured victims decreased from the year 1970 significantly and sustainably while at the same time the share of slightly injured pedestrians increased [10].

Per definition for the official Statistics of the Federal Republic of Germany as slightly injured all victims are counted who are injured after an accident and for example treated ambulant but not taken into hospital for inpatient treatment (of at least 24 hours). Increasing shares of slightly injured victims may for example indicate a reduced level of impact velocities as it was the case for pedestrians in speed-reduced urban areas (speed limit 30 km/h).

Severely injured are persons who were immediately taken to hospital for in-patient treatment (at least for 24 hours). Killed are victims who died immediately after the accident or within 30 days as a result of the accident. An increase of the share of severely injured in combination with a decrease of the share of killed victims may indicate improvements in the rescue chain and for the treatment of severely injured persons in the hospital. Appropriate indications are not recognizable for rides of motorcycles from the diagram shown with Figure 6.

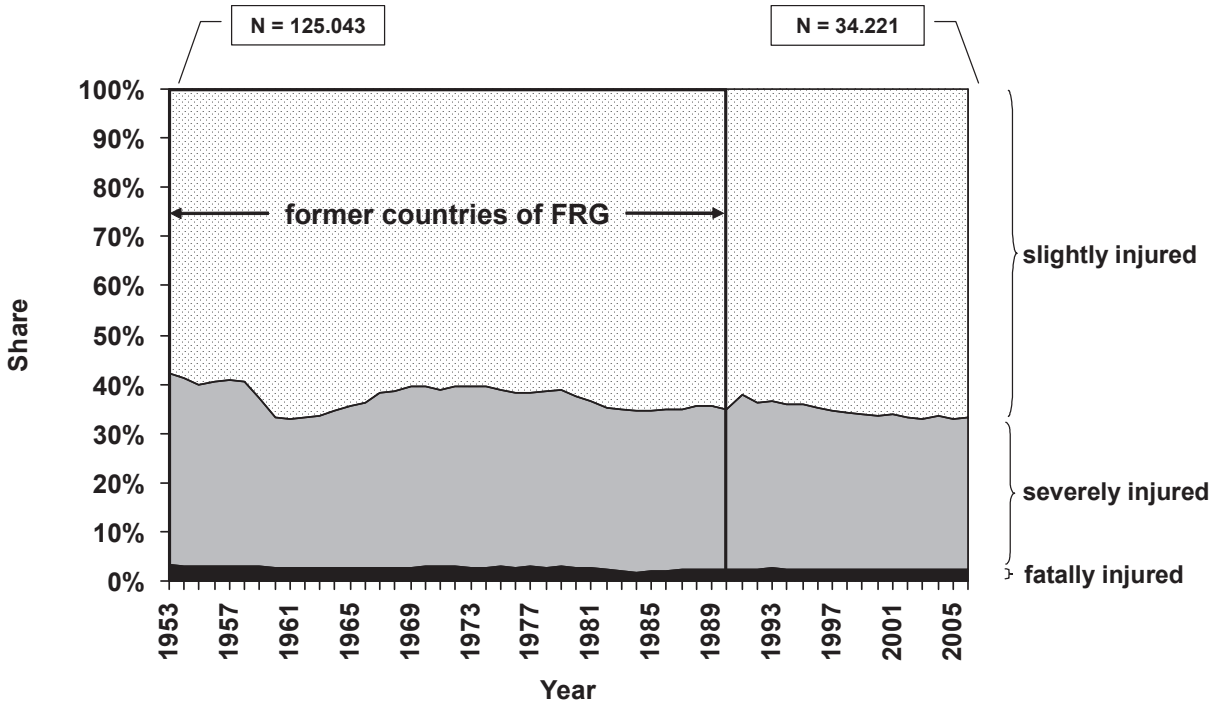

Figure 6: Shares of slightly injured, severely injured and killed occupants of motorcycles bearing an official registration number, in road-traffic-accidents in the Federal Republic of Germany at any year from 1956 to 2006 (Source: StBA)

2.6 Shares of killed motorcycle riders related to all fatalities

As shown with Figure 7, in the year 1953 the killed drivers and passengers of motorcycles and motor scooters with 36% formed the biggest share of all 11,449 killed road-accident victims in the Federal Republic of Germany. This was followed by the shares of pedestrians (30%) and of users of Mofas, Mopeds and Mokicks (17%). At that time the killed occupants of automobiles (cars, buses and coaches, agricultural tractors, commercial vehicles and remainders) with a share of 15% did follow only on rank four of all killed traffic accident victims.

This was changed drastically afterwards with increasing figures of automobiles coming into traffic. For the year 1970 the share of killed car occupants of all 19,193 victims killed in traffic accidents was 46%, followed by the share of killed pedestrians (32%). With a share of only 4% of all fatalities the killed motorcycle rides did play a relatively marginal role in these years.

The share of killed drivers and occupants of motorized two-wheelers bearing an official registration number was 9% out of 11,300 killed traffic accident victims in total in the year 1991. After the occupants in cars with a share of 60% and the pedestrians with a share of 17% the motorcycle riders have been in that year already on rank number three.

In 2006 the killed drivers and occupants of motorcycles bearing an official registration number formed the second frequent group of all killed victims of traffic accidents in that year. Their share was 16% out of 5,091 and herewith bigger than the share of killed pedestrians with 14%.

With smaller absolute figures of all persons killed in traffic accidents the relative importance of motorcycle riders did increase in the younger past. For further reductions of the figures of all traffic participants killed in accidents, the strategic and operational significance of the motorcycles increased correspondingly.

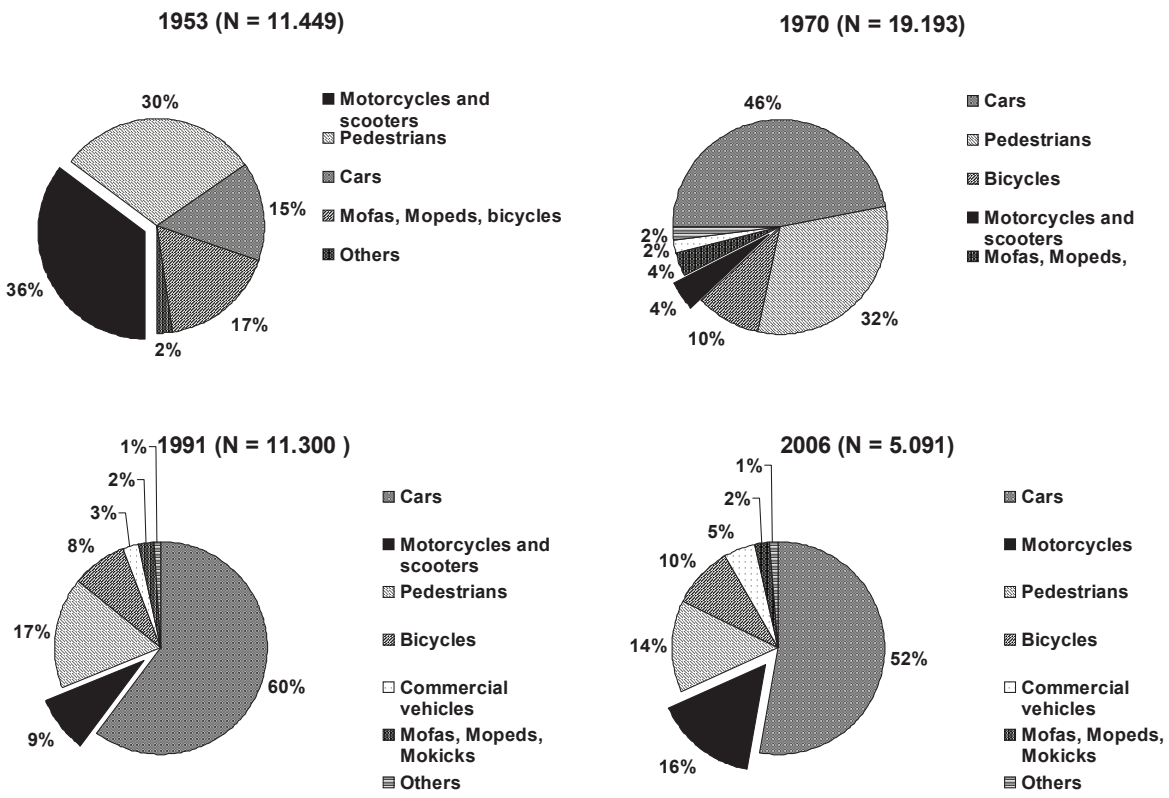

Figure 7: Shares of traffic participants killed in traffic accidents in Germany in the years 1953, 1970, 1991 und 2006 (Source: StBA)

This is also reflected by a multitude of recent research activities amongst others within the research programme of the European Union, some of them are still running.

An example is the project **MAIDS** (**M**otorcycle **A**ccident **I**n-**D**epth **S**tudy, see www.maids-study.eu). Herein for the years 1999 and 2000 a total of 921 accidents involving motorized two-wheelers in France, Germany, Italy, the Netherlands and in Spain have been collected to contribute in the further exploration of the causes and consequences of these accidents.

Settled within the ongoing projects running under the 6th Framework Programme is the integrated project **APROSYS** (**A**dvanced **Pro**tection **Sys**tems, duration from April 2004 until March 2009, see www.aprosys.com) by which in the sub project SP 4 motorcycle accidents are analysed. First results have been reported with [19].

Also currently in process are the projects **SIM** (**S**afety **I**n **M**otion, see www.sim-eu.org) und **PISa** (**P**owered Two-Wheeler **I**ntegrated **Sa**fety, see www.pisa-project.eu). Amongst the objectives of SIM is the identification of a feasible safety strategy for powered two wheelers. Thereto the primary (active) safety to avoid accidents as well as the secondary (passive) safety to reduce the consequences of an accident shall be enhanced. All aspects and findings shall be incorporated into the prototype of a new safety powered two-wheeler. As a result of PISa reliable and dependable integrated safety systems for a series of powered two wheelers are announced. As a result a considerable improvement of the primary safety of powered two-wheelers regarding the handling and driving stability should be reached. Herein also the benefits of secondary-safety systems are considered. As a result of the PISa project two prototypes will be developed to demonstrate the potential of integrated systems for a reduction of frequency and severity of accidents with powered two-wheelers involved.

3 CURRENT SITUATION AND TRENDS

3.1 Age groups of killed motorcycle riders

Amongst the phenomena worthy of mention for the current progression of the accident occurrence with motorcycles involved is the age distribution of the drivers. Figure 8 illustrates the shares of the different age groups for killed riders of motorcycles bearing an official registration number in accidents on German roads for the years 1991 to 2006. There in the year 1991 the share of the under 25 years old victims was laying just at 49% (485 from 992 in total). Until the year 2006 this share has been reduced almost by half down to 25% (196 from 793). Accordingly the shares of the older motorcycle riders did increase. For example in the year 1991 only 7% (69) of the killed drivers and passengers of motorcycles were 45 years old or older. The share of this age group was quadrupled until the year 2006 up to 28% (219). The share of the seniors with an age of 65 years or more did increase from 1.4% (14) in the year 1991 up to 4.5% (36) in the year 2006 and with this figures it was more than tripled.

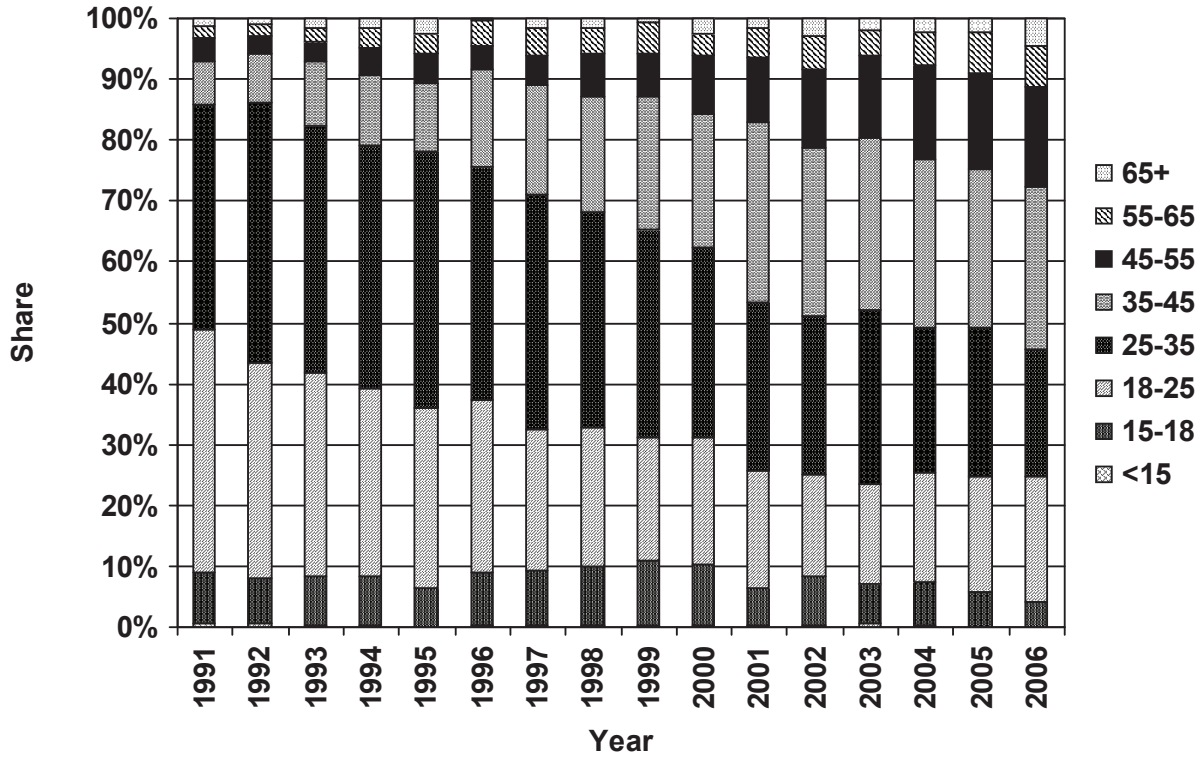

Figure 8: Shares of the age groups of riders of motorcycles bearing an official registration number killed in traffic accidents in Germany within the time period from 1991 to 2006 (Source: StBA)

As a result of these shifts of the ages of motorcycle riders involved as victims in traffic accidents additional actual challenges came up for the further development of the safety of motorcycles. It is in general well known, that the ability to withstand biomechanical loads is lesser for elderly people as for the younger. Correspondingly greater is the personal injury risk in road-traffic accidents, especially for the so called “unprotected road users” [11]. Some more restrictions follow as a consequence of the influence of age to the driving performance. Facts as increasing reaction times, weakening of sight and hearing abilities, restrictions with the motility and the sagging of muscular forces lead to limitations with the safe steering of motorized vehicles for elderly when participating in the “modern” road traffic. At this juncture the influence of drugs (medicine) shall also not be underestimated [12]. For this it follows that the system containing men, motorcycle and surrounding has to be further

investigated to support the mobility of elderly motorcycle riders so that their road-traffic risk compared to younger riders will not increase excessively.

3.2 Regional scattering of risks

Not only international, but also for the national regions it is worthwhile to analyse and compare the accident occurrence. Also here, the figures published within the official statistics give a very useful basis. Corresponding to the figure of inhabitants the length of the road network and of the vehicle population in Germany, most of the motorcycle riders are involved in accidents occurring in the bigger states in Western Germany and the smallest figures are given for the small city states of Bremen and Hamburg, see Figure 9.

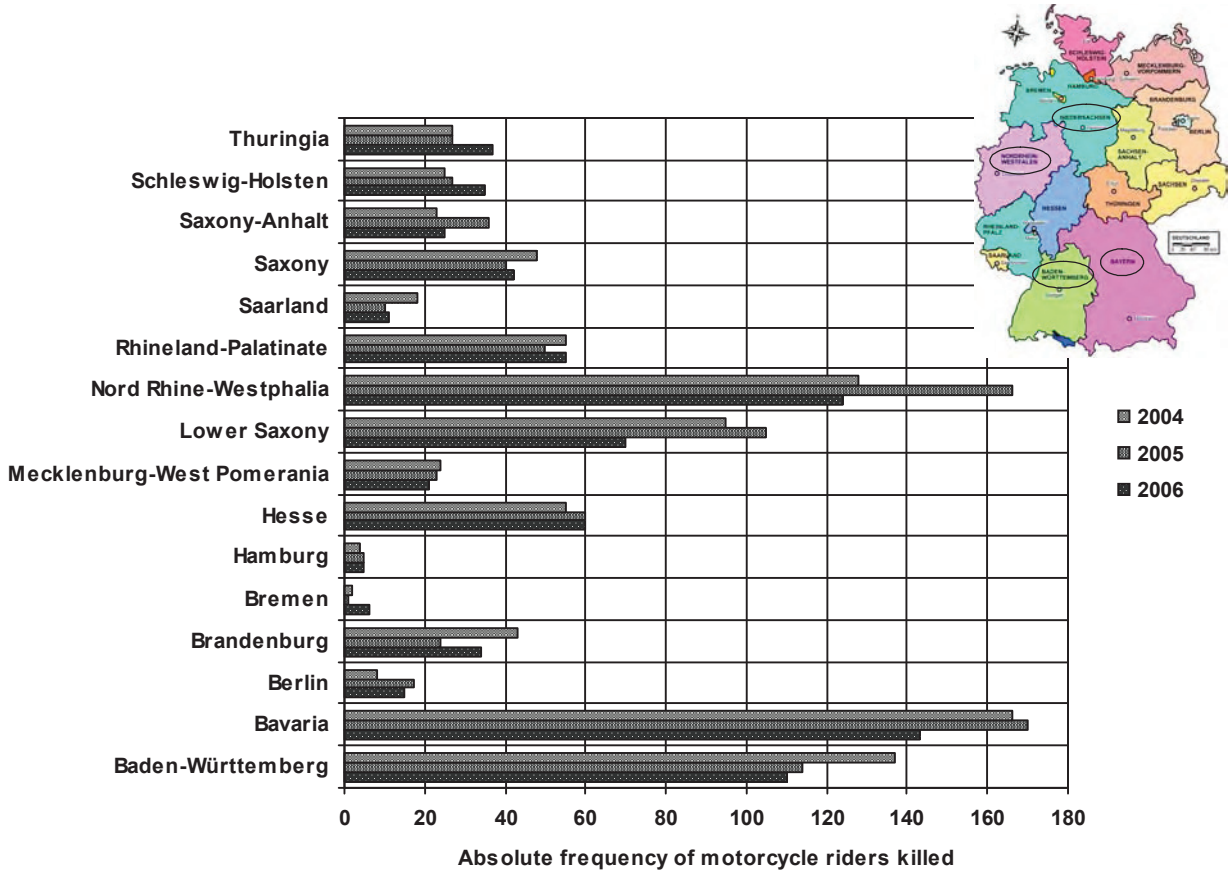

Figure 9: Absolute figures of drivers and passengers of motorcycles bearing an official licence number killed in traffic accidents occurring in the different states of Germany in the years 2004, 2005 and 2006 (Source: StBA)

In the year 2006 in Bavaria 143, in North Rhine-Westphalia 124 and in Baden-Württemberg 110 motorcycle riders have been killed in traffic accidents. At the other end of the absolute-frequency ranking of the year 2006 in Hamburg 5 and in Bremen 6 motorcycle riders have been killed.

With reference to the corresponding vehicle-fleet population the relations shown with Figure 10 exist. Herein for the year 2006 the fatality risk was highest in the Eastern German states Thuringia (45 killed per 100,000 motorcycles), Mecklenburg-Western Pomerania (39 killed per 100,000 motorcycles) and Brandenburg (36 killed per 100,000 motorcycles).

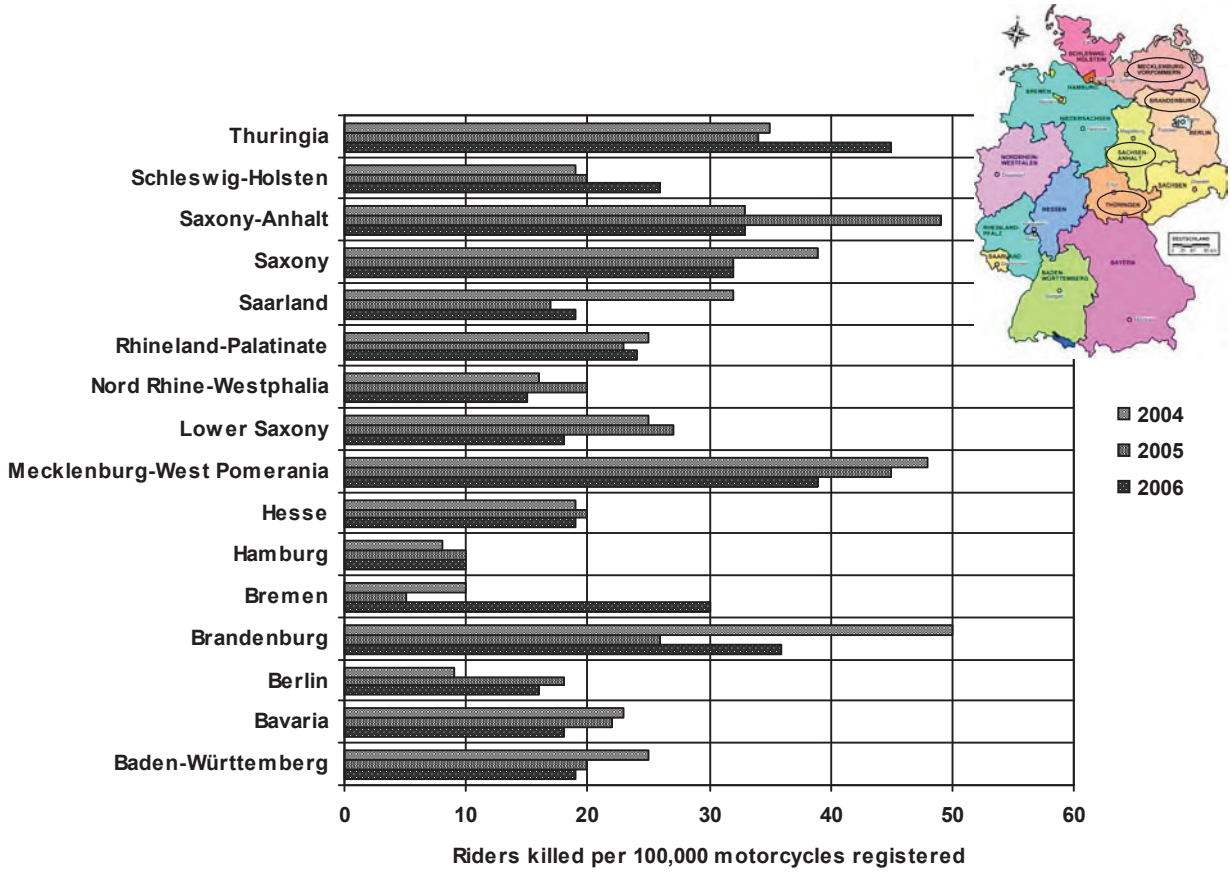

Figure 10: Drivers and passengers of motorcycles bearing an official licence number killed in traffic accidents occurring in the different countries of Germany per 100,000 corresponding vehicles registered in the years 2004, 2005 and 2006 (Source: StBA)

These values are not constant and may differ for several years with great variations. Therefore corresponding alterations are possible year by year for the chronological sequences of the several states as for the ranking of the states among each other.

Nevertheless, using these figures a potential for regional measures to improve the safety of motorcycle riders can be disclosed, see Table 3. In doing so it was assumed for the year 2006 that the risk based on the motorcycle fleet population for those countries laying over the average risk value for Germany was reduced exactly down to this value of 20 killed motorcycle riders per 100,000 motorcycles registered. Therewith in the states concerned the absolute figures of killed motorcycle riders would be reduced from 18% (Rhineland-Palatinate) to 54% (Thuringia). This means in absolute figures a reduction in all the states concerned (and therewith also for the entire German Federal territory) by 91 motorcycle riders. Based on the 793 killed motorcycle riders in Germany in the year 2006 this would be a relative reduction by 11% anyhow.

Why to, this calculation shows that the largest potential for reducing the absolute figures of killed motorcycle riders in Germany is given for those states where the most motorcycle riders are killed in traffic accidents. With the average of the years 2004 to 2006, the streets in the smaller city states Hamburg, Bremen and Berlin seem to be relatively safe for motorcycle riders. But for example the situation in Bremen does also point out, how smaller variations of the absolute figures already may result in extensive variations of the risk figures. The number of killed motorcycle riders relating to 100,000 motorcycles registered here was 10 in the year 2004, divided in half in the year 2005 down to 5 and sextupled in the year 2006 up to 30. For the risk ratio discussed here with only one killed motorcycle rider in the year 2005 (see Figure 9) the ideal “goal of zero” has temporarily almost been reached.

Since the risk for severe accidents is clearly greater on rural roads than inside urban area, for the assessment of the risk ratio based on the vehicle population in large-area states also the corresponding distribution of the roads has to be considered.

With this background a reduction of the average value of 20 killed motorcycle riders per 100,000 motorcycles registered down to 15 seems to be an optimistic projection. Why to, seeing the real-world risk figures in some countries, this could be educed as a "best-practice" approach. Out of this anyhow the figure of killed motorcycle riders would be reduced relatively by 25%. This would result into a reduction of the absolute figure of killed motorcycle riders in Germany for the year 2006 by 198 down to 595.

Table 3: Killed riders and passengers of motorcycles bearing an official licence number for the individual states of Germany in the year 2006 related to the corresponding vehicle-fleet population and assumption for regional reductions

State	**Killed motorcycle riders**	**motorcycle fleet population**	**killed riders per 100,000 motorcycles actual value**	**killed riders with the assumption of maximal 20 killed riders per 100,000 motorcycles**	**Killed riders difference**
Baden-Württemberg	110	578.529	19	110	0
Bavaria	143	775.278	18	143	0
Berlin	15	94.307	16	15	0
Brandenburg	34	94.375	36	19	-15 (-44%)
Bremen	6	20.243	30	4	-2 (-33%)
Hamburg	5	48.746	10	5	0
Hesse	60	312.189	19	60	0
Mecklenburg-West Pomerania	21	53.225	39	11	-10 (-48%)
Lower Saxony	70	387.554	18	70	0
North Rhine-Westphalia	124	825.714	15	124	0
Rhineland-Palatinate	55	225.174	24	45	-10 (-18%)
Saarland	11	58.626	19	11	0
Saxony	42	132.041	32	26	-16 (-38%)
Saxony-Anhalt	25	76.552	33	15	-10 (-40%)
Schleswig-Holstein	35	136.876	26	27	-8 (-23%)
Thuringia	37	82.832	45	17	-20 (54%)
Germany	**793**	**3.902.512**	**20**	**-**	**-91 (-11%)**

3.3 Allocation of the accidents over the months of a year

In particular because of the usage of a motorcycle as an additional vehicle for leisure times its traffic participation and therefore also its involvement in accidents depends considerably on seasonal effects. For many motorcycle riders adverse weather and worse road conditions may be reasons not to use their motorcycle in the road traffic. Often motorcycles are decommissioned during winter months.

Therefore most of the motorcycle accidents occur during nice weather in the warmer seasons. These are the months were also the regional trips and more extended motorcycle tours are organized more frequently. With this background it becomes clear that for those months with normally nice weather conditions in Germany the figures of killed motorcycle riders increases drastically especially on rural

roads. Figure 11 illustrates the absolute figures of killed occupants of motorcycles bearing an official licence number in Germany over the specific months in the years 2004, 2005 and 2006.

Normally the motorcycle season begins in April and ends in October. Noticeably low was the figure of killed motorcycle riders outside urban area in August 2006. The official comment of the Federal Statistics mentioned that it could be explained by extremely foul weather conditions for this month [6].

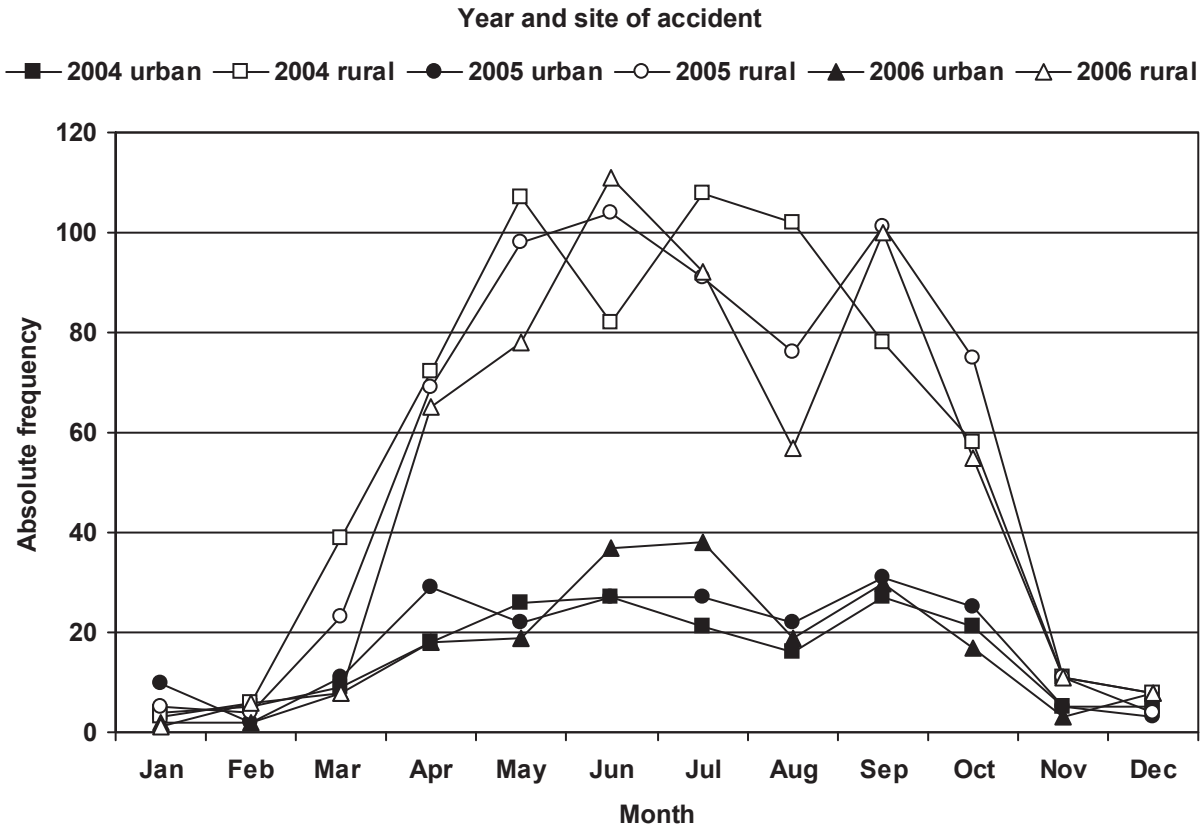

Figure 11: Monthly distributions for killed occupants of motorcycles bearing an official registration number outside and inside urban area in Germany for the years 2004, 2005 und 2006 (Source: StBA)

3.4 Personal-related misbehaviour of motorcycle riders

Proceeding from their personal judgement, the police officers recording the accident describe the causes of the accident in the survey form according to the list of possible causes which has been in force since 1975. A distinction is made between general causes (among other things road conditions, weather factors, obstacles), which are attributed to the accident and not to the individual road user involved, and personal-related misbehaviour (such as failure to give precedence, driving too fast, etc.), which is attributed to the individual driver, vehicle rider or pedestrian, i.e. the road user involved. This means that up to eight causes per accident can be registered.

Amongst others, the official statistics account for the personal-related misbehaviour per 1,000 road users involved in accidents. Correspondingly Figure 12 depicts the misbehaviour of the drivers of motorcycles bearing an official registration number involved in accidents with personal damage in Germany for the year 2006.

Driving too fast (that often means speeding) is the most frequent misbehaviour charged to motorcycle riders by the police officers recording the accident. In the year 2006 this was the case for 21% of all 33,782 motorcycle riders involved in an accident with personal damage.

A more detailed breakdown according to the driver´s age shows, that in all age groups driving too fast is the most frequent police-recorded misbehaviour.

It is remarkable that this occurred even for less then 15-years old motorcycle drivers (who obviously do not own the appropriate driving licence, see Table 1). For the year 2006, according to the statistics 21 motorcycle drivers in this age group have been involved in an accident with personal damage. For nine of these drivers (43%) the police officer assigned that driving too fast was their personal related accident causation.

For the age groups above 15 years the share of driving too fast within the police-recorded personal misbehaviour increases up to the 21-25 years old drivers. Here approximately 300 out of 1,000 motorcycle drivers are involved in accidents attributed by driving too fast. With increasing driver age this share decreases. However, even for the more than 65 years old drivers driving too fast is still the most frequently assigned personal accident causation. Also relatively frequent are personal failures to observe priority and to give precedence as well as mistakes when overtaking. This is the case for all age groups with an exception for the seniors who are 75 years old or older and the under 15 years olds.

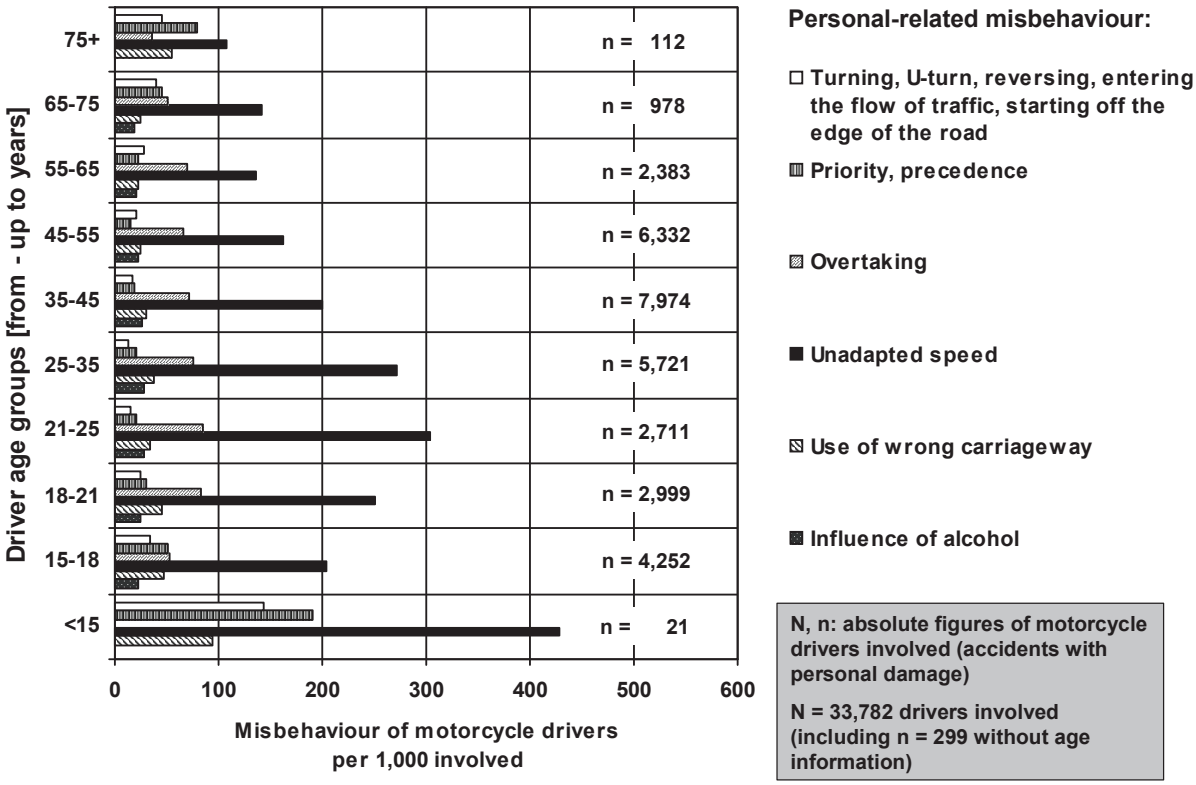

Figure 12: Misbehaviour of drivers of motorcycles bearing an official registration number per 1,000 involved in accidents with personal damage in the year 2006 in Germany subdivided for different age groups (Source: StBA)

In general, with increasing age of the motorcycle riders the percentage of personal-related misbehaviour per 1,000 drivers involved declines. This is caused primarily by the decrease of driving too fast as assigned personal accident causation and can be understood as an indication of a more carefully driving behaviour of the elderly motorcycle riders. Compared to the younger but already driving-experienced age groups and the middle-aged drivers conspicuous for elderly drivers is the relatively large share of misbehaviour related to disregarding of precedence and to turning, U-turning, reversing, entering the flow of traffic or starting off the edge of the road. For the more than 75 years

old motorcycle drivers also the wrong carriageway plays a relatively significant role amongst the low absolute figures of personal-related misbehaviour in this age group. This may indicate problems for elderly people to cope with complex road traffic situations.

3.5 Type of Accident

For drivers of motorcycles bearing an official registration number who are categorized as mainly responsible party (that is the person who in the opinion of the police is chiefly to blame for the accident) the official statistics also contain tabulations showing figures and details for the so called "types of accident". The type of accident describes the conflict situation which resulted in the accident, i.e. a phase in the traffic situation where the further course could no longer be controlled because of improper action or some other cause. The following seven types of accidents are distinguished: Driving accident, accident caused by turning off the road, accident caused by turning into a road or by crossing it, accident caused by crossing the road (that is an accident caused by a conflict between a vehicle and a pedestrian), accident involving stationary vehicle, accident between vehicles moving along in carriageway and other accidents (which cannot be allocated to the other types of accidents mentioned before).

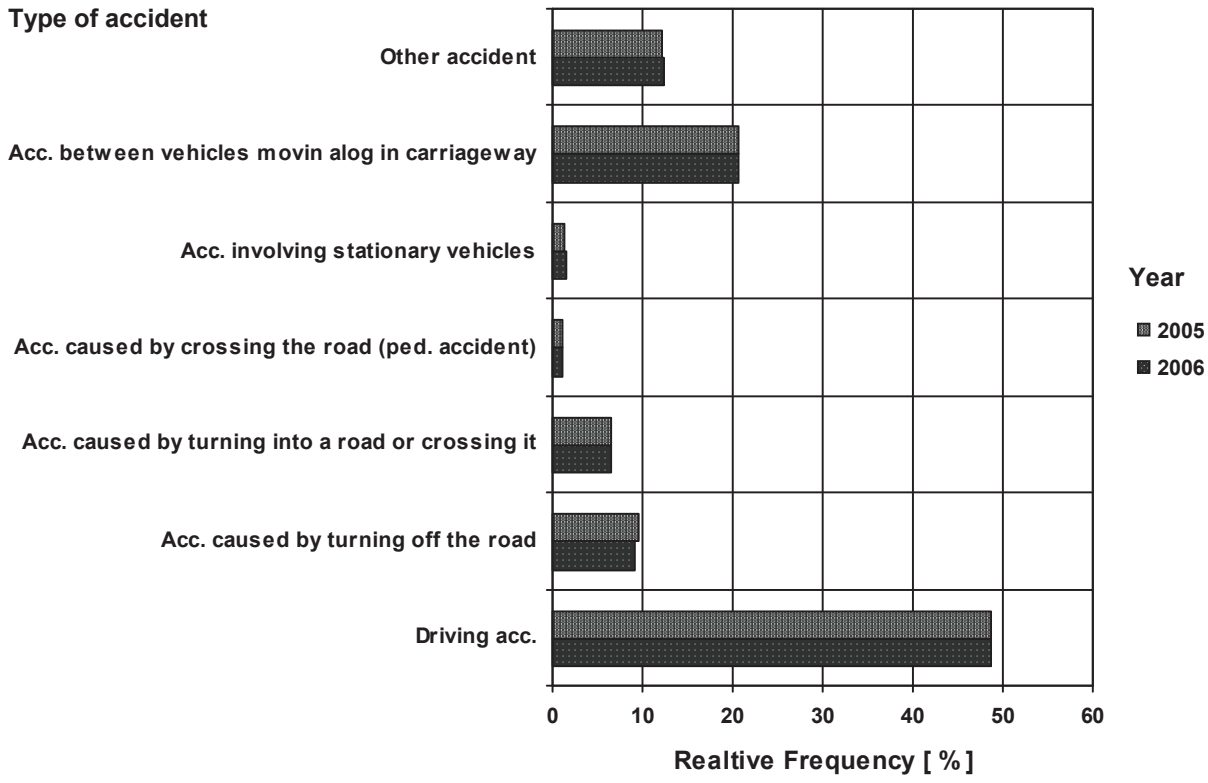

Figure 13: Relative frequency of the accident types in accidents involving personal injury and with drivers of motorcycles bearing an official registration number allocated as main responsible party for the years 2005 and 2006 in Germany (Source: StBA)

In the year 2006 in total 15,956 accidents with personal damage occurred with the rider of a motorcycle bearing an official registration number have been allocated as being the main responsible party of the accident. This is a share of 47.2 % of all 33,782 road users which have been involved in these accidents.

For 2005 the corresponding figure was 16,610 accidents involving personal damage and drivers of motorcycles allocated as the mainly responsible party (47.1% of all 35,242 road users involved in these accindets). As illustrated with Figure 13, the so called driving accident dominates these accidents.

The official definition is that "a driving accident is caused by the driver losing control of his vehicle without other road users having contributed to this. This could be due to unadapted speed or misjudgement of the course or condition of the road etc.. As a result of uncontrolled vehicle movements, however, a collision with other road users may have happen. A driving accident however does not include accidents in which the driver lost control of his vehicle due to a conflict with other road users, an animal or an obstacle on the carriageway, or because of sudden physical incapacity or a sudden defect of the vehicle. In the course of the driving accident, this vehicle may collide with other road users, so that this is not necessarily a single vehicle accident".

With this background the dominance of the driving accident may again advise to a problem of unadapted speed for motorcycle riders killed in traffic accidents. When assessing this share it should also be kept in mind, that for motorcycle single accidents per definition for the official statistics always the motorcycle driver is the main responsible party. Accordingly a big share of single accidents is contained in the accidents of which the distribution of accident types are shown in Figure 13.

Second most frequent is the accident between vehicles moving along in carriageway. In the year 2006 with this type of accident 99 motorcycle drivers as the mainly responsible party have been killed. The corresponding figure for the year 2005 is 133. This is a share of 12.5% of all killed occupants of motorcycles bearing an official registration number in Germany for the year 2006, respectively a share of 15.2% for those killed in the year 2005. The accident between vehicle moving along in carriageway is described as an accident caused by a conflict between road users moving in the same or opposite direction, unless this conflict belongs to a different type of accident.

3.6 Opponents

Most of the riders and passengers of motorcycles bearing an official licence number killed in traffic accidents have been involved in crashes with a car as opponent, see Figure 14. In the year 2006 the corresponding absolute figure was 296 killed riders (37% of all 793 riders killed in this year). 96 of them had been fatally injured in urban-area accidents and 200 on rural roads. Second most frequent are killed riders in single accidents (264 respectively 33%). 57 were killed in accidents inside urban area and 207 outside urban area.

In single accidents and in accidents with two parties involved the sum of killed drivers and passengers of motorcycles bearing an official registration number in Germany for the year 2006 is 686. In accidents with more than two parties involved 107 riders (13.5% of the 793 riders killed in total) lost their lives.

The vast majority of accidents with two parties involved are crashes with only the motorcycle rider(s) and no opponent killed. In the year 2006 inside urban area in such crashes 119 motorcycle riders and 10 opponents (one car occupant and nine pedestrians) lost their lives. In corresponding accidents on rural roads 303 motorcycle riders and 26 opponents (two riders of Mofas, Moped or Mokicks, eight car occupants, one occupant in a commercial vehicle, six bicycle riders and nine pedestrians) have been killed. To understand this it has to be considered that the crash resulting into a fatality of a vehicle occupant is not always the first impact (with the motorcycle). It also may happen that after a (slight) first impact another severe impact with a rigid obstacle or a vehicle rollover follow. In this way it is possible, that even in an accident with a motorcycle and a heavy truck involved the occupant of the truck gets killed.

Altogether the analyses show that in accidents occurring inside urban area the greatest potential for a reduction of the figures of killed riders of motorcycles bearing an official registration number is evident for motorcycle/car crashes. Though the official statistics do not give any information on the speed of the vehicles involved, it can be assumed that the level of the travelling speeds as well as the

level of the impact speeds is normally significantly lower in the accidents inside than outside urban area. With this background the relatively high share of single accidents with 57 killed riders on urban roads is remarkable.

For the accidents on rural roads the potential for reducing the absolute figures of killed riders on motorcycles bearing an official registration number is clear greater than for accidents inside urban area. Here again motorcycle/car crashes are on focus as well as motorcycle single accidents and on rank number three are accidents with motorcycles and commercial vehicles involved.

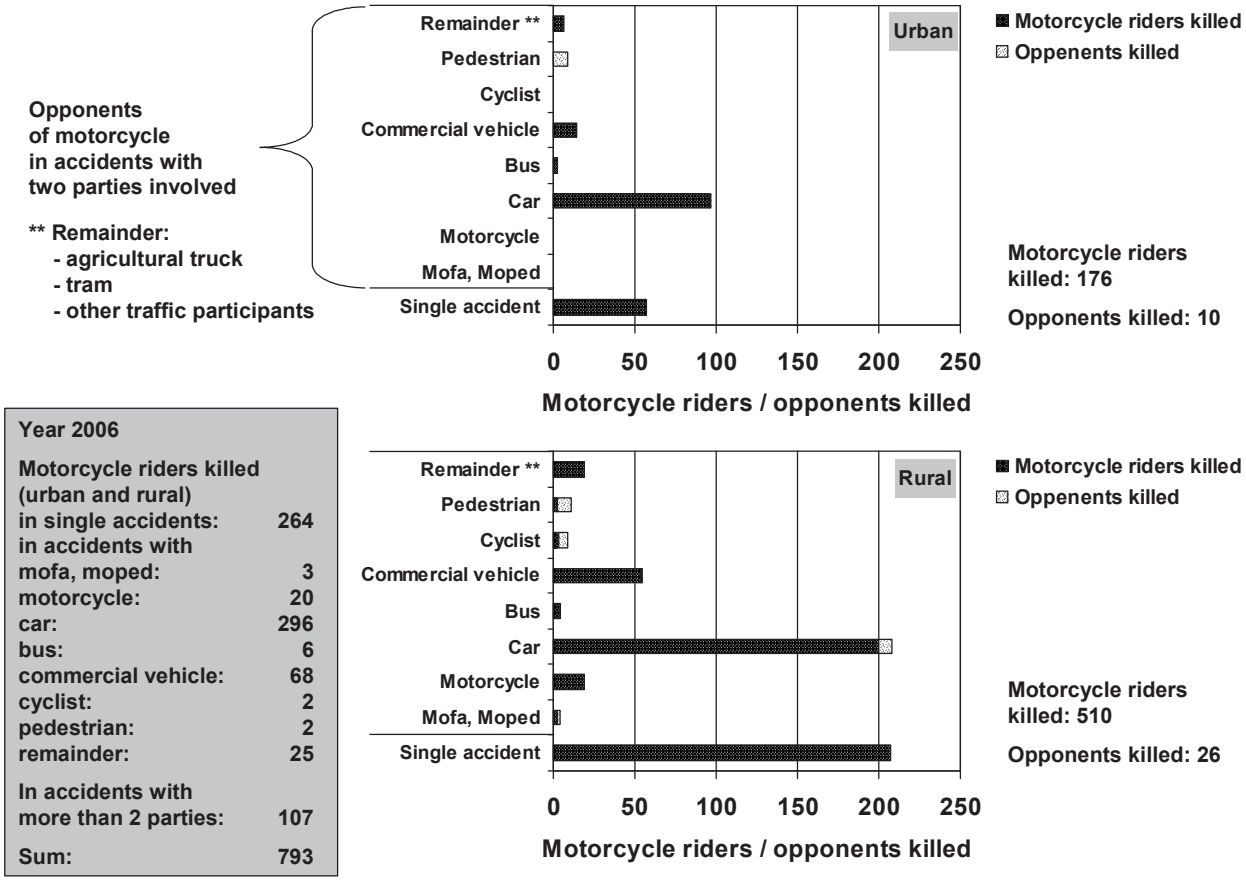

Figure 14: Killed drivers and passengers on motorcycles bearing an official registration number as well as opponents separated to motorcycle single accidents and motorcycle accidents with two parties involved in Germany for the year 2006 (Source: StBA)

All other accident scenarios, for example motorcycle accidents with pedestrians or with bicyclists involved are, from the statistically point of view, only very low significant. This is true for the killed motorcycle riders as well as for the killed opponents.

Special emphasis for the further research and development should be paid for improving the primary (active) safety of motorcycles to ovoid single accidents as well as for improving the secondary (passive) safety to reduce the consequences of crashes with cars (and at lower priority also to lower the consequences of crashes with commercial vehicles) [13]. When striving for improvements of the passive safety amongst others the protection clothing of the riders and, if applicable, protection measures at the motorcycle itself should be further analysed and developed. Measures to damp the forces of impacts of motorcycle riders against stationary obstacles, for example rigid posts of roadside barriers, should be considered, too [14, 15].

4 FINDINGS FROM IN-DEPTH-STUDIES

The official accident statistics for Germany do not comprise any information and parameters on the details of the collisions, for example impact speeds, impact locations at the vehicles involved or impact pulse directions with corresponding angles. Furthermore detailed information on the injured body parts and body regions of the accident victims corresponding to the international technical classifications which are in use for this are not covered by the official German statistics. Therefore, for more detailed descriptions and analyses of the occurrence and the outcomes of traffic accidents so called in-depth-analyses are running in the framework of research projects to permanently or temporarily collect information on real-world accidents to be stored in case collections and data banks. Hereunto the following descriptions give some insights that may be useful for a deeper understanding of the accident occurrence with motorcycles involved.

A problem of motorcycle accident research based on in-depth-studies are in general the relatively low case figures. Time and time again this becomes conspicuously with analyses of the great variations of the characteristics of motorcycle accidents. Variant are the degrees of freedom for the movement of the motorcycle and the rider(s) even before the first impact and as well during the follow-up movements and impact events. Manifold are the classes and types of motorcycles and scooters or the features and quality of the protection clothing of driver and passengers. Hence the results of in-depth analyses may often only be insufficiently statistically validated. But in particular combined with superordinated findings extracted from the official statistics, in-depth analyses can give precise insights into the real-world occurrence and important cognitions of potentials of possible measures for improvements of the safety and for lowering the risks of injuries of motorcycle riders.

4.1 Representative Scenarios

Latest findings regarding the most important accident scenarios of motorcycles come from the EU-funded research project TRACE (TRaffic Accident Causation in Europe, see http://www.trace-project.org). Amongst the objectives of TRACE is an update of knowledge about the accident causations. As a result of an analyses of descriptive accident databases in Germany, United Kingdom, France, Spain, Italy, Greece and the Czech Republic for motorcycles 4 representative accident scenarios were found for motorcycles, Figure 15.

It was found that the most important scenario is the motorcycle single accident on rural roads. With this accidents the motorcycle may run-off the carriageway, have a rollover on the carriageway or collisions with roadside restraint systems like steel barriers for example. The share of this configuration amongst the analysed fatal or serious motorcycle accidents is 27%. On rank number 2 with a share of 13% are front-side accidents in rural and urban junctions with a motorcycle and a car as the opponent. This is followed by a scenario with the motorcycle and a car impacting side by side in rural and urban non-junctions. This type of collision involves 5% of the fatal and serious motorcycle accidents analysed within the TRACE project. Another 5% share was found for scenarios with the motorcycle impacting the rear end of a car or a car impacting the rear end of a motorcycle both on rural and urban non-junctions. All in all these four scenarios cover 50% of the fatal or serious motorcycle accidents occurring on European roads in the years 2001 to 2004 and analysed within the TRACE project.

For these scenarios amongst the primary factors causing the accidents, as reported as first results of the TRACE project, are perception failures and decision failures of the motorcycle driver and/or car driver. As contributing factors for example for 16% of the single accidents (scenario 1) too fast/inadequate speed and/or unsafe acts of the motorcycle rider have been allocated. For scenario 2 a car-driver perception failure was assigned as a contributing factor for 70% of the accidents. This results have been generated by using in-depth case descriptions coming from the MAIDS database for the main motorcycle accident scenarios (see Figure 15) found in the previous European-wide statistical analysis. In General it was found that the main causes of the accidents are human failures. The most frequent human error was a failure perceiving the motorcycle by another

vehicle driver (associated to the traffic environment, traffic-scanning error, lack of other vehicle driver attention, faulty traffic strategy or low conspicuity of the motorcycle driver).

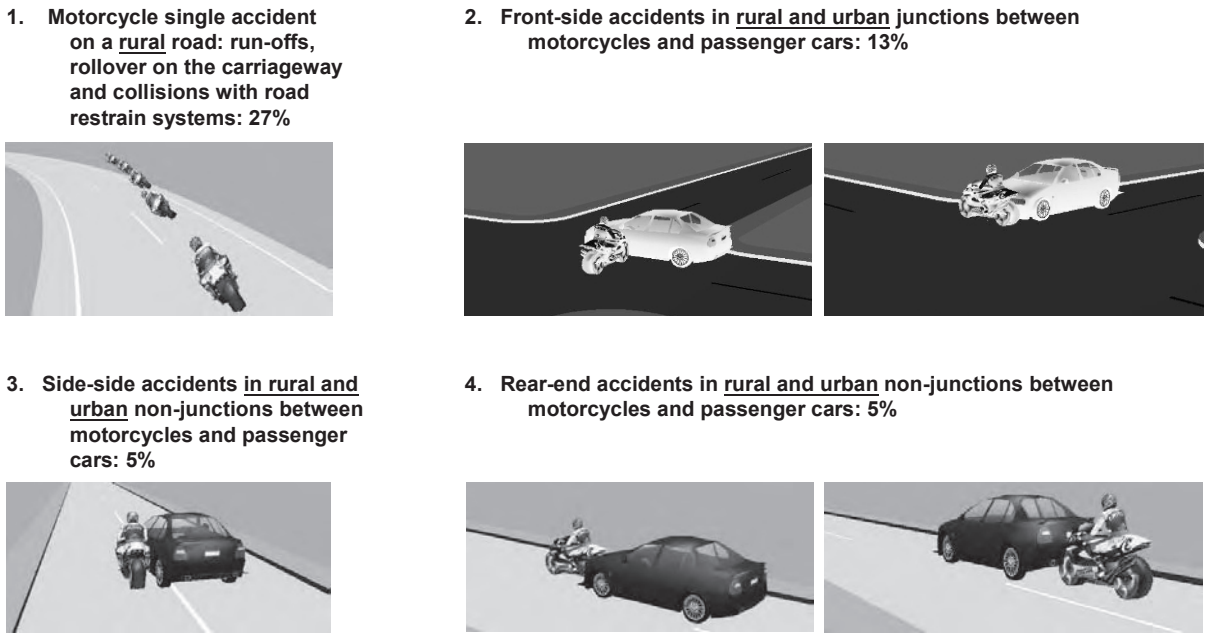

Figure 15: Representative accident scenarios for fatal and serious motorcycle accidents that are found as a result of the TRACE project

4.2 Impact constellations for accidents involving a car and a motorcycle

For the development of secondary (passive) safety measures to protect the motorcycle rider in accidents with a motorcycle and a car involved it is useful to know all corresponding impact configurations and their frequency in the real-world accident occurrence. Therefore in a first step of the accident analyses, cases have to be discriminated with the motorcycle and the rider driving upright at the begin of the first impact from other cases with the motorcycle already inclined or even fallen down to the road surface before the first impact with the opposing vehicle. In addition, for the cases with the motorcycle sliding with the side on the road surface, meaningful is a further classification depending on either motorcycle and rider(s) are moving still close together or are separated. Within the research project APROSYS the TNO-MAIDS database and the DEKRA motorcycle-accident database have been analysed in this way.

For all upright motorcycle impacts Figure 16 shows the distribution of the impact configurations coded using three digits as per ISO 13232 [13]. The first digit describes the impact location at the motorcycle, the second digit the impact location at the car and the third digit the heading angle between the longitudinal axes of the vehicles at the begin of the first impact.

Amongst the suitable motorcycle accidents in the DEKRA database (174 cases in total) configurations 115 and 114 are most frequent. Here the motorcycle impacts frontally onto the front of the car. With configuration 115 the angle between the longitudinal axis of the vehicles is near 180° (opposite-direction impact). In configuration 114 the motorcycle comes more inclined from ahead. It is remarkable that this scenario is not amongst the main motorcycle/car-accident scenarios found within the TRACE project.

In the DEKRA database the configuration 131 (a car impacts with its front the rear-end of a motorcycle, as part of the TRACE configuration 4) counts for 10 cases out of 174 according to a share of 5.7%. The configuration 711 with the motorcycle impacting frontally onto the rear-end of a car (the other part of TRACE configuration 4) counts for another 7 cases (4%) in the DEKRA database. So

with a sum of 17 cases (9.8%) the TRACE configuration 4 could be treated as an important scenario also within the DEKRA database.

Corresponding to the TRACE scenario 2 are the impact constellations 413 with the motorcycle running perpendicularly into the side of the passenger compartment of the car and constellation 143 with the car hitting frontally the side of the motorcycle. Amongst the DEKRA cases constellation 413 counts for 6 cases and constellation 143 counts for 12 cases. The sum of 18 cases represents a share of 10.3% out of all 174 cases in the DEKRA data base which is somewhat smaller then the TRACE result (13%).

TRACE scenario 3 corresponds roughly to the impact scenarios 641 and 241 as coded corresponding to ISO 13232 whereas a total side by side collision (341, 441, 541) is not detected here. Constellation 641 with the motorcycle impacting sidewise the rear edge of a car counts for only 1 case and constellation 241 with the car impacting with its front edge the side of a motorcycle counts for 6 cases in the DEKRA database. So the sum of 7 cases represents a share of 4 % which is similar to the share of 5% for the scenario 3 as a result of the TRACE project.

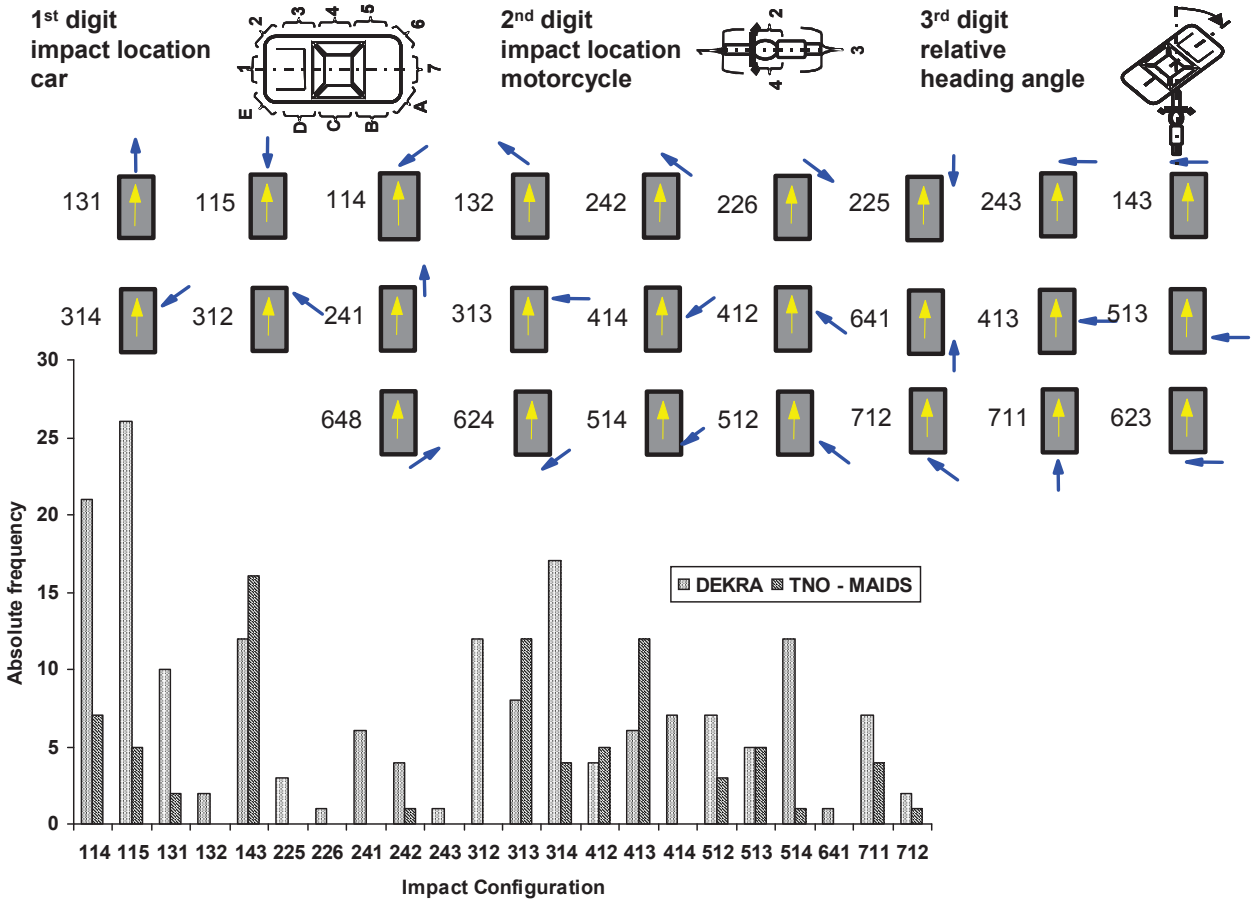

Figure 16: Definition von impact constellations in motorcycle/car collisions
as per ISO 13232 and corresponding distributions found in the motorcycle accident data bases
from TNO-MAIDS as well as from DEKRA

Most frequent in the TNO-MAIDS database is constellation 143. Here the car impacts perpendicularly onto the side of the motorcycle. Also relatively frequent in the TNO-MAIDS database are the constellations 313 and 413. In both constellations the motorcycle hits the side of the car perpendicularly. In constellation 313 the impact point at the car is located in front of the passenger compartment. For constellation 413 the motorcycle impacts directly into the compartment.

Constellation 413 is one of the most important impact constellations for the assessment of a motorcycle airbag [17]. In spite of wearing a protection helmet the face of the motorcycle driver may impact directly through the visor opening onto the stiff roof edge of the car. The consequences could be a severe or fatal head injury and fatal neck fractures.

Altogether Figure 16 illustrates the variety of real-world motorcycle impacts, which is in this juncture with the limitation to upright motorcycle impacts already reduced. Accordingly complex is the estimation of the benefit potential and the risk/benefit ratio for measures to improve the secondary (passive) safety of motorcycles, for example with a motorcycle airbag.

Regarding the severity of motorcycle-rider injuries, Figure 17 illustrates results coming from an analysis of GIDAS data within the research project SIM. The accidents happened on urban and rural roads in the GIDAS investigation areas inside and around the cities of Hanover and Dresden in the years 2002 and 2003. Corresponding to the case-collection criteria of GIDAS in the accidents at least one person was injured. In general the GIDAS database with approx. 2,000 accidents per year is in line with criteria for a database which is (if necessary combined with weighing factors) representative for all accidents in Germany (see www.gidas.org). Within the database used 56 accidents involving injured or killed riders of Mofas, Mopeds and Mokicks as well as 202 accidents involving injured or killed riders of motorcycles have been analysed.

The collision speeds of the Mofas, Mopeds and Mokicks were in the range of 0 to 55 km/h. For the motorcycles the collision speeds were 0 to 185 km/h.

Within GIDAS, the injuries for the individual body regions are coded as described with the Abbreviated Injury Scale AIS which is internationally accepted and in use. Herein MAIS stands for the MAximal Injury Severity of a person coded with the maximal AIS-value for a certain body region. AIS = 0 indicates uninjured, AIS = 1 minor injury, AIS = 2 moderate injury, AIS = 3 serious injury, AIS = 4 severe injury, AIS = 5 critical injury and AIS = 6 maximum injury, that means with the actual status of medicine not treatable. AIS = 6 often is also indicated as “unsurvivable”. But studies of the National Trauma Database in the USA have shown for example that for persons who sustained just one injury and this injury was coded by AIS = 6 there was a mean probability of survival by 21%. Relating to the probability of survival for the accident victims the figure of their (severe) injuries and their physical constitution as well as the possibilities for treatment in the certain hospital play also a role.

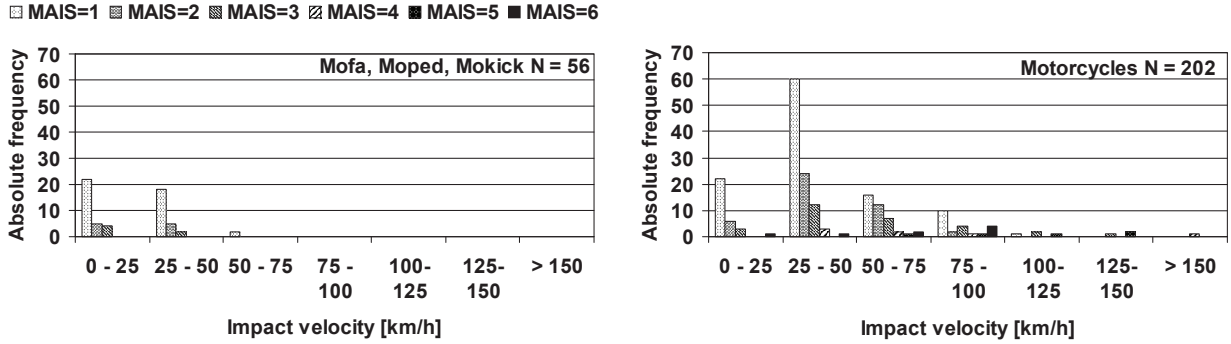

Figure 17: Injury severity of the occupants of Mofas, Mopeds und Mokicks as well as of motorcycles within different sub-groups for the impact velocities of the powered two-wheelers (Source: GIDAS, accident years 2002 and 2003)

For the riders of Mofas, Mopeds and Mokicks and for the riders of motorcycles in the classes of impact speeds of 0 up to 25 km/h and of more than 25 up to 50 km/h the minor injuries (MAIS = 1) are clearly most frequent. Amongst the cases studied, for the Mofas, Mopeds and Mokicks no rider injures have been found to be coded with AIS = 4+ (severe, critical or maximal injured). In contrast to

this for the motorcycle riders in both of the low impact-velocity classes one person could be found who was maximal injured (MAIS = 6). This indicates, that not only the impact speed of a powered two-wheeler but also additional circumstances of the accident, for example the impact speed of the opponent, may influence significantly the injury severity of the powered-two-wheeler rider.

With greater impact velocities it can be seen for the riders of motorcycles that even in the sub groups of more than 50 km/h up to 75 km/h and of more than 75 km/h up to 100 km/h the minor injured (MAIS = 1) are most frequent. But accounting the smaller absolute figures of cases within these sub groups the relative shares of more severe injured motorcycle riders increases significantly.

In total amongst the 202 motorcycle riders only 8 persons have been injured by the degree MAIS = 6. The corresponding collision speeds of the motorcycle are 5 km/h, 30 km/h, 62 km/h, 67 km/h, 84 km/h, 2times 92 km/h and 95 km/h. This tends to a conformitation of the influence of higher speeds to the risk of a motorcycle rider of being killed in a traffic accident. But it is really a question whether on the basis of eight motorcycle riders suffering injuries classified with MAIS = 6 the accident occurrence of roughly 800 killed motorcycle riders could be described adequately.

In the year 2006 due to road accidents in Germany 10,590 occupants of motorcycles bearing an official registration number have been seriously injured and 793 have been killed (see clause 2.5). That indicates that 13 seriously injured counts for one killed motorcycle rider. So a representative sample of 200 seriously or killed Motorcycle riders would contain only 11 killed riders. This shows a basic dilemma for the statistical analyses of a sample of in-depth cases which is representative for the accident occurrence for the injured and killed motorcycle riders in a given region: Because only a relatively small number of cases can be sampled in a year using elaborate in-depth cases, to gather an appropriate figure of cases with killed accident victims it is necessary to combine several years. On the one hand this needs several years of time for the collection. On the other hand it could be that after completion of sampling the topicality of all cases in the whole sample is no longer up to date enough.

Insights into the accident occurrence of 289 motorcycles (> 125ccm) during the so called pre-crash phase as a result of further analyses of GIDAS data within the research project SIM are displayed with Figure 18. Thereby the powered two-wheeler did drive before the first collision far predominantly on a straight and dry road. In 185 cases (64 %) the driver of the motorized two-wheeler did brake.

Braking before the impact is one of the most important measures to reduce the severity of an accident in terms of reducing the kinetic energy of the motorcycle as much as possible for which the velocity counts squared. All the more this is essential for a motorcycle at higher speeds driven in the pre-crash phase. It is well known, that for a stable upright breaking of a motorcycle it is necessary that especially the front wheel is not locked. With a conventional brake system the motorcycle rider operates by hand the lever for the front-wheel brake and by foot the lever for the rear-wheel brake. In this way the brake forces are distributed independently to the wheels of a motorcycle. Therefore as a consequence of the dynamic alteration of the axle loading the highest brake force can be applied by the front wheel. To avoid a locking of the front wheel in order to avoid a downfall, many motorcycle riders do not capture the maximal possible brake force. As a consequence the deceleration respectively the reduction of the speed of a motorcycle in the pre-crash phase is not optimal. In this juncture an anti-lock brake (ABS) can help.

As also shown with Figure 18, amongst the 289 accident-involved powered two-wheelers only three (1%) have been equipped with ABS. This discloses an appropriate high potential for the improvement of the safety of motorized two-wheelers driving on our roads today.

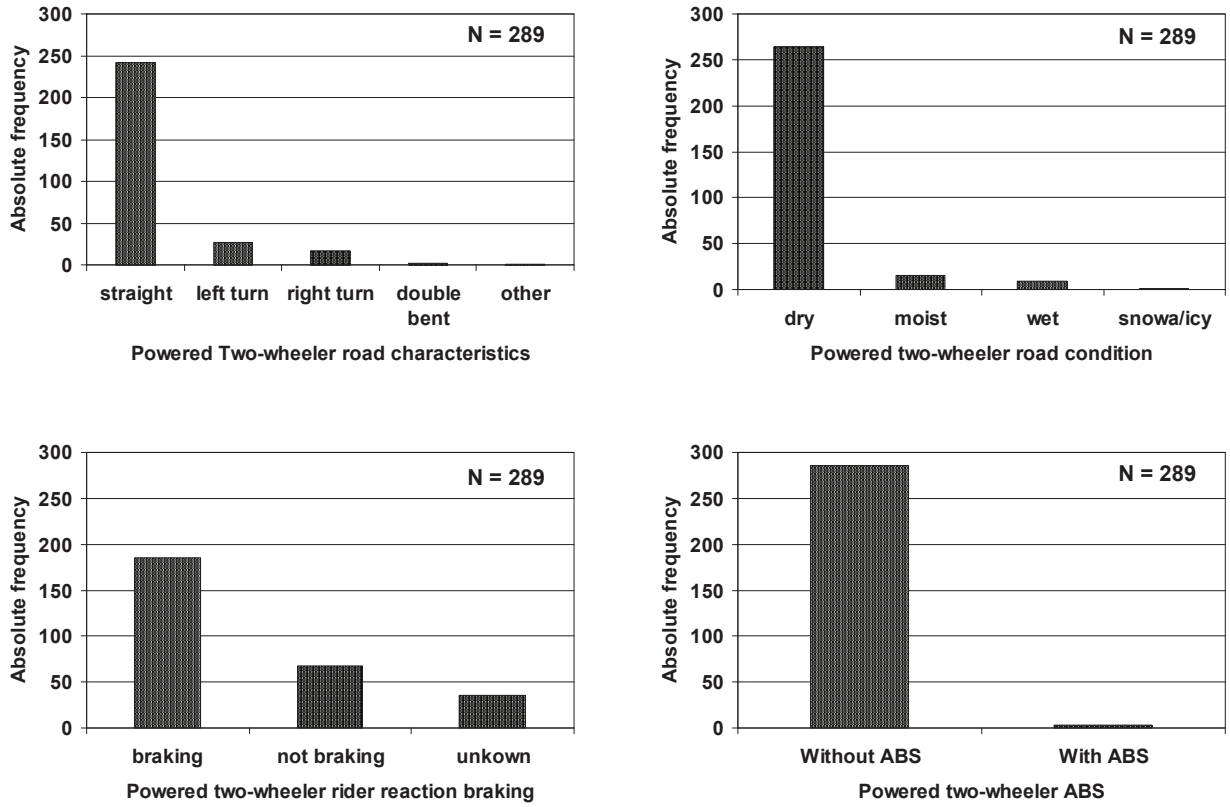

Figure 18: Results of the analyses of the pre-crash phases in 289 accidents involving motorcycles, (source: GIDAS, accident years 2002 and 2003)

5 SUMMARY OF RESULTS AND OUTLOOK

Despite enormous progress in safety that can also be assessed for the accident occurrence of motorcycles during decades now, there is still a big need for further improvements. Recently in Germany, for the occupants of a motorcycle bearing an official registration number the risk of being killed in a traffic accident based on the figure of corresponding vehicles in the fleet is more than three-times as high as for car occupants and the occupants of Mofas, Mopeds or Mokicks. Based on the mileage this risk is even twelve times higher than the appropriate risk for car occupants and 2.6 times higher than for the occupants of Mofas, Mopeds and Mokicks.

Whereas in Germany since the 1970ies the absolute figures of killed roads users did predominantly decrease significantly and sustainably, this was not always true for the motorcycle riders. Here, during the last years the absolute figures of killed road-accident victims remained more or less constant, whereas indeed the absolute figures of motorcycles registered in the fleet increased considerably. Within the smaller absolute figures of road-traffic accident victims of recent years the relative share of killed riders of motorcycles bearing an official registration number increased. In the year 2006 this share was 16% (out of 5,091 killed road users in total) and increased again to 17% (out of 4,958 killed road users) according to the preliminary figures for the year 2007. According to this, the strategic and operational importance of motorcycle accidents for further long-term reductions of the figure of killed road users in Germany is rising.

The emphasis of the occurrence of serious motorcycle accidents is placed on the streets outside urban area. Here – compared to accidents on urban roads – in general an increased potential of danger is evident for motorcycle riders due to higher speeds driven by the motorcycles as well by other traffic participants. Despite the protection clothing which is normally worn by the drivers of motorcycles bearing an official registration number, the motorcycle riders are amongst the unprotected vulnerable road users with an associated injury risk.

In serious accidents with motorcycles involved the vast majority of killed road users are the motorcycle riders itself. Herein the most important role play the motorcycle single accidents and the crashes with a motorcycle and a car involved.

As a result of the In-depth-analyses using GIDAS most of the motorcycle accidents occur on straight and dry roads.

Amongst the evolutions which are remarkable for the last year is the considerable enlargement of the share of elderly motorcycle riders. This is in line with the modified usage of a motorcycle as a vehicle in leisure times for an outstanding and fascinating feeling of motorized mobility. Herewith the accident occurrence of motorcycles depends also from the weather conditions. In particular nice weather with an increasing participation of motorcycles in the road traffic is recently one of the often mentioned causes for an increase of serious motorcycle accidents. Vice versa for a reduction of the frequency of killed motorcycle riders seasonally foul weather is often stated as a main reason.

It remains a very actual challenge for accident research to collect information and to describe the accident occurrence of motorcycle accidents for appropriate analyses and assessments. As shown with examples in the article this can be done with insightful results by using the Federal Statistics in combination with in-depth-studies. Despite of the brad variability of the motorcycle accident occurrence clear key aspects can be detected with promising courses of action.

In addition to measures for improving the secondary (passive) safety, for example a motorcycle airbag, especially measures for improving the primary (active) safety for example the ABS for motorcycles show a great potential for future enhancements of the safety of motorcycles. A precondition is, that such state-of-the-art safety systems are available not only for expensive luxury motorcycles.

Above all, the individual who is driving a motorcycle must be on focus. For him or for her the particular risks of driving a motorcycle have always and ever to be aware.

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