EFFECTS OF ROAD GRIP ON BRAKING FOR INJURY SEVERITY OF CAR ACCIDENTS IN GERMAN TRAFFIC SCENERY BASED ON IN-DEPTH ACCIDENT STUDY GIDAS

Otte, Dietmar, Jänsch, Michael, Nehmzow, Joachim
Accident Research Unit, Hanover Medical School, Germany

ABSTACT

On the basis of accident documentations GIDAS (German in-Depth-Accident-Study) the influence of different grip values between tires and road surfaces leading to an impact speed in accidents involving cars have been analyzed. The assumption is defined as influence of the braking grip value varying by ± 10 % for dry road surface situation and ± 15 % for wet on the real accident documentations for resulting injury severities of passengers and/or external traffic participants. The background of this study approach is oriented on better tires that could decrease the portion of most severe or fatal injured persons in road traffic accidents.

It could be established an average by 2.0% on the reduction of most severe or fatal injured persons and a reduction of accidents with severe injured persons by 1.8% in average, if the grip value would be plus 10 respectively 15%. There would be an increase of the number of accidents with most severe or fatal injured persons by 2.0% and of accidents with severe injured persons by 7.0%, if the rip values would be reduced by minus 10 respectively 15%. The highest rates of reduction or increasing injury severity could be established for pedestrians and bicyclists.

KEYWORDS: Active Safety, Injury Severity, Tires, Brake deceleration, Statistics

IT IS ASSUMED that optimized tires can lead to a higher friction coefficient between the tire and the road surface, resulting in a reduced braking distance of cars in dangerous situations and thus reducing collision speed following in a correspondingly reduction of the resulting injury severity. With this it can be assumed that a higher friction coefficient can increase traffic safety. But there are a lot of parameter influencing the effect of friction between tires and road surface, i.e. conditions of tire and road material, structure of tire profiles, road surface etc. An assessment of the advantages of better tires is very difficult, in praxis there are on one hand different tires with different performance capacity on the market, on the other hand in life duration of a tire the grip value is reduce by use. Even there will be a mixture of good and worst grip values in the fleet of cars on the road. In the accidents sample there are very different conditions existing. A scientific question of this study was to answer the question; what could be reached by better grip values regarding the accident outcome of injury severity.

Such task of the study requires a very detailed accident analysis of comprehensive information from the accident field including a determination of the brake distance, the prior driven velocities and also the impact speed, but also a representative description of the accident scenarios occurring in traffic. To this end accident compilations collected on site are suitable, for these the data of GIDAS (German In-Depth-Accident-Study) are used for this purpose.

The friction coefficient between the tire and the road surface theoretically depends on the surface structure of the road and also of the tire composite as well as on the tread pattern, thus characteristics, which cannot be verified within the complex interrelation of real-world traffic accidents with differing road and weather conditions, at best they may be assessed. For every collected accident in GIDAS all traces are documented as brake distance, final position of vehicles/persons and a calculation of driving and impact speed was carried out by true to scaled drawings of all traces and the scenery.

In the course of this study it has been assumed that a reduction of the brake distance of 10 to 20% can be realized in practice. This assumption was stated on the experiences of some test series carried out with tires on the market (TCS, 2009) based on existing performances of tires on the market validated on mea-

surements. Tires are loosed their performance over the time of use, especially under 4mm, TCS stated a loss of performance of around 10% comparing new tires versus 4mm. For the study it was assumed that the effect regarding a difference of grip value of good and worst tires can be seen over the whole life duration of a tire has no influence, because a consideration of this effect would not be possible on the documented car fleet in the accident sample. The objective of the study is to record the changed influence on the resulting injury severity of occupants and /or external traffic participants, such as pedestrians and cyclists, by changing the grip values on a plus minus delta-grip, for instance ± 10 % for dry and ± 15 % for wet road surface situation to determine the potential for accident prevention based n a scientific approach.

Every accident comprises a reaction phase, which is succeeded by the application of the brakes. For the accidents having occurred, frequently the time or the distance was insufficient for preventing a collision. If the vehicle can be stooped due to a high mean deceleration before a looming collision or if the speed can be lowered for an inevitable collision, a lower impact speed and with this a potential for increased safety in traffic would be given.

In order to evaluate this potential from accident data, special re-calculation of existed case collections at the sites of accidents within GIDAS are carried out.

The accident collection GIDAS provides detailed information of statistically representatively collected traffic accidents in the areas Hannover and Dresden and are predestined for this study because of their method of collection and up to 3,000 different data sets. A scientific collection team documents approximately 2,000 accidents annually and reconstructs the accident scenarios (Otte, 2003; Brühning, 2005). The drawings of the sites of the accidents and the traces are based on a photogrammetric measurement based on 3-D-Laserscan (Otte, 2005). The distances taken into account for the reconstructions of the accidents have been measured on site by a research team and the deceleration have been set to empirically assessed mean deceleration values, all values have been recorded in EDP-compatible formats and can be used again in the context of the issue addressed above, of a virtual 10 or 15% increase or decrease, for the calculation of so-called "virtual driving and virtual collision speeds". Then the influence of the velocity on injury severity based on previous findings of injury risk curves is used for a recalculation given the new virtual impact avoidance speed using injury risk graphs, can be assessed for the consequences of injuries due to a change in road grip value. Beside the official injury severity classification, GIDAS encodes and lists all injuries in accordance with the AIS Abbreviated Injury Scale (Association for the Advancement of Automotive Medicine, 1998), which can then be used to determine the ISS Injury Severity Score and injury risk curves for the assessment of this study approach.

DATA BASIS OF THE STUDY

The study primarily contains a selection of all accidents with personal damage involving a car and a specified period of accident occurrence. The data basis of the study is focused on:

Accidents of cars M1with personal injury differentiated in accordance with the type of collision and the accident partners involved: motorcar, truck, bicycle, motorcycle, pedestrian.
Accidents of Hannover and Dresden during the collection period July 1st 1999 to June 30th, 2008

A representation in compliance with the official accident statistics of Germany and their definition should be warranted by statistical random selection and weighting procedure, in order to permit projections to the accident situation in all of the Federal Republic of Germany. The results of the study should be adopted the injury severity of the national statistics, which is classified as slight (out-patient), severe (in-patient) and fatal (died within 30 days).

During this period of 8 years altogether n= 17 052 traffic accidents with personal injury have been collected by GIDAS, of these
11,400 reconstructed traffic accidents are available, involving a total of 16,337 motorcars.

The complete motion sequence of a vehicle including all has been recorded, and the distances between the collisions as well as that up to the first collision and to the final position have been documented. For all distances the decelerations as well as the accelerations have been stated as “mean decelerations” and corresponding to the velocity values has been recorded. This so-called “sequence analysis” is used for the study, to recalculate the whole motion by given “virtual collision speed” based on a new alteration of the mean deceleration (grip) value of ± X%. X has been defined from empirical values of the range of variance of possible friction coefficients, based on experimental experiences (Wies et al, 2006), which tires are reached on different road surfaces and different weather conditions in practice.

Figure 1 shows the influence of the "10%-criterion" in a path-velocity diagram for a mean deceleration (grip) of 8 m/s², the changes for a lower deceleration (-10%) or a higher one has been depicted for this example.

For an initial braking speed of 50 km/h, for instance a 10% change in deceleration results in a braking distance altered by 1.1 m, for a speed of 100 km/h as much as 4.4 m.

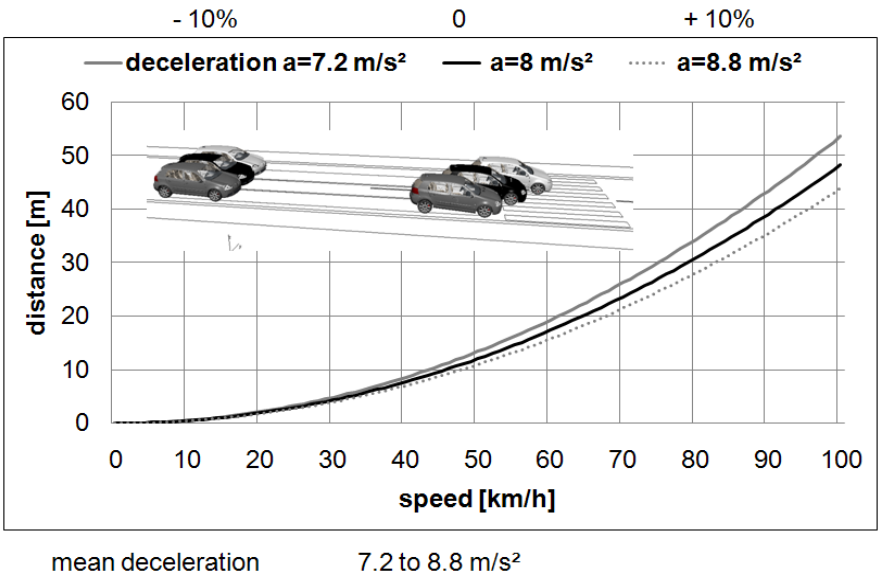

Figure 1 Length of Brake Distances of Motorcars for Mean Deceleration 8 m/s² demonstrating the effect of plus minus 10% difference

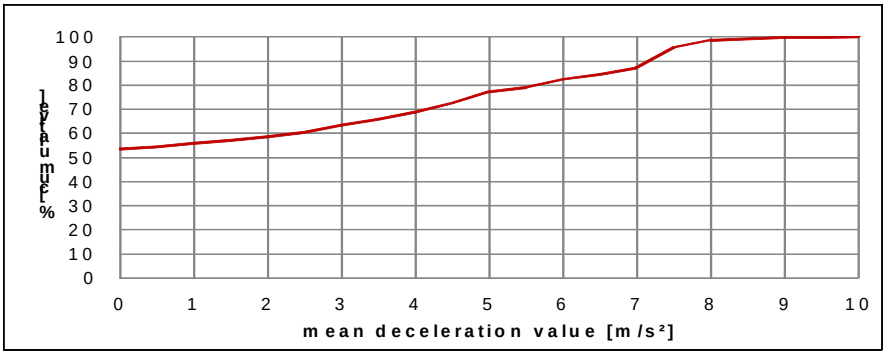

Figure 2 Distribution of mean deceleration values used in the reconstruction of all cases

For assumptions of better or diminished grip values, the technical data of an accident was used to calculate a virtual collision speed, so called avoidance speed. If this will be Zero, the vehicle would have reached a full stop before a collision. It can also be checked, if the determined virtual collision speed is

lower than the avoidance velocity, in this case the accident would also have been avoidable. The following definitions of avoidance are used in the study:

- the accident is ***spatially avoidable*** for an involved person, if for the braking deceleration the place where the accident had occurred had not been reached
- the accident is ***temporally avoidable*** for an involved person, if for the braking deceleration the place where the accident had occurred had been reached at a later point in time and this time period had been sufficiently long for the accident partner to leave the place where the accident occurred.

To be able to evaluate the avoidances assessments, only collisions of cars involved in frontal collisions have been regarded. Collisions with the rear or the side of a motorcar can only be analyzed confidently, if the collision partner did not move (stationary objects or vehicles). For head-on impacts no avoidance can be calculated by standard formulas. Collisions with pedestrians and bicyclists all seemed analyzable, if they collided with the front of the car. Half of all accidents of cars occurred frontally (51.1% of all, 56.8% of severe and fatal accidents), accidents with impacts on objects are comparatively rare (4.7% / 8.5%).

Further assumptions had been taken for the calculation of the influence of tires:

- the vehicle has to be in motion at the time a reaction of the driver occurs
- the driver has reacted
- the driver has stepped on the brake

Table 1 Brief Description of Study Tasks of Tire Conditions for Parameter of Accident Avoidance

mean deceleration	**higher** +10% dry, +15% wet	**lower** -10% dry, -15% wet
impact speed	lower or none	higher
reaching impact point	later or never	earlier

For the determination of the avoidance the calculation initially based on the real collision speed of the vehicle traditionally determined from the lengths of the skid marks and the assumption of a mean braking deceleration value, taking also into account the distance traveled during reaction time. Specifying an improved or deteriorated braking deceleration (Table 1), the mathematical computerized reconstruction was now carried out once again for the period from the reaction up to the time of the collision.

The mean deceleration value for dry road surfaces was varied by ± 10% and for wet surfaces by ± 15% based on an assumption.

The new results were then used to conduct an avoidance analysis based on a case-by-case basis. For that an aggregated sample is used, to be able to differentiate the data into avoidable and diminishable.

INFLUENCE OF A CHANGE OF GRIP VALUE ON THE MEAN BRAKING OF CARS ON THE COURSE OF THE ACCIDENT AND INJURY SITUATION

For 45.6% of all accidents involving motorcars resulting in personal injury no influence can be determined, in 21.2% the collision speed would be lower. For 30.3% of the accidents a calculation was impossible. These impossible cases are not considered in the representation, shown in Figure 3, where for 65.4% of all motorcar accidents had no influence by plus grip values of 10 / 15 %. In 29.6% of the cases the collision speed is calculated lower, in 1.4% a temporal and in 3.6% a spatial avoidance results. In particular for severe accidents a reduction of the collision speed is discernible. For accidents involving motorcar resulting in severely/fatally injured persons the collision speed was lower in 40.9% of the cases. The percentage of temporally and spatially avoidable cases (1.9% temporally and 3.2% spatially avoidable), however, has the same distribution as for all accidents.

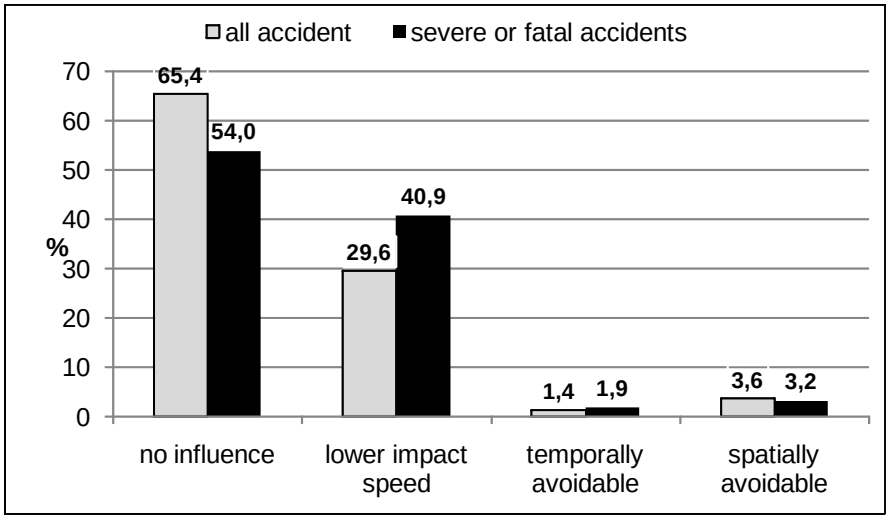

Figure 3 Possible Effects of grip value **plus** 10 respectively 15% assumption

Due to a higher grip value, a shorter brake distance is realized, resulting in a lower collision speed (Figure 4). The calculation for "none influence of grip change" in the graph resulted from those accidents, for which no braking deceleration value could be determined.

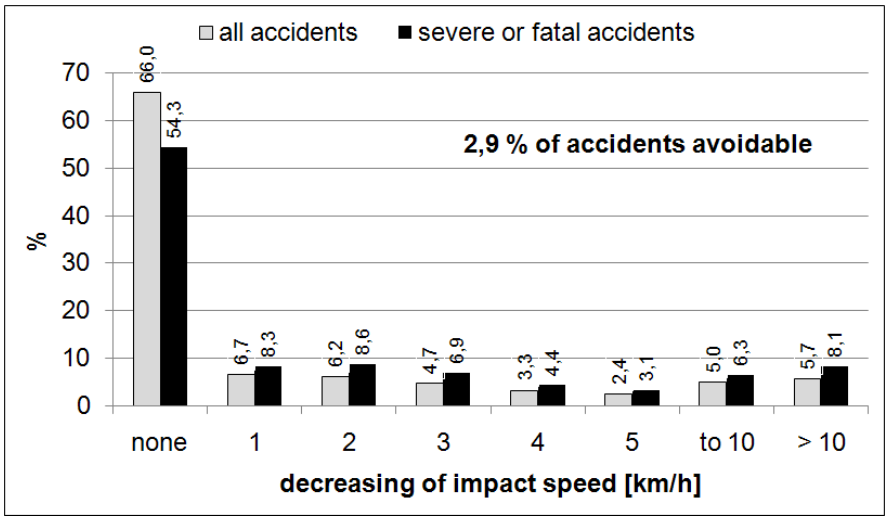

Figure 4 Possible Effects of grip value **plus** 10 respectively 15% on the Collision Speeds

For a change of grip value minus 10/15% in 37.2% of the accidents involving motorcars a collision speed increased by 37.2% results, for severe accidents even in 50% of the cases (Figure 5). After all, with lowered friction 5% of the accidents would have occurred at velocities of 5 to 10 km/h higher and even 5.7% of the accidents at speeds of more than 10 km/h above the one they really occurred (Figure 6). For severe accidents a significantly higher increase in velocity occurred.

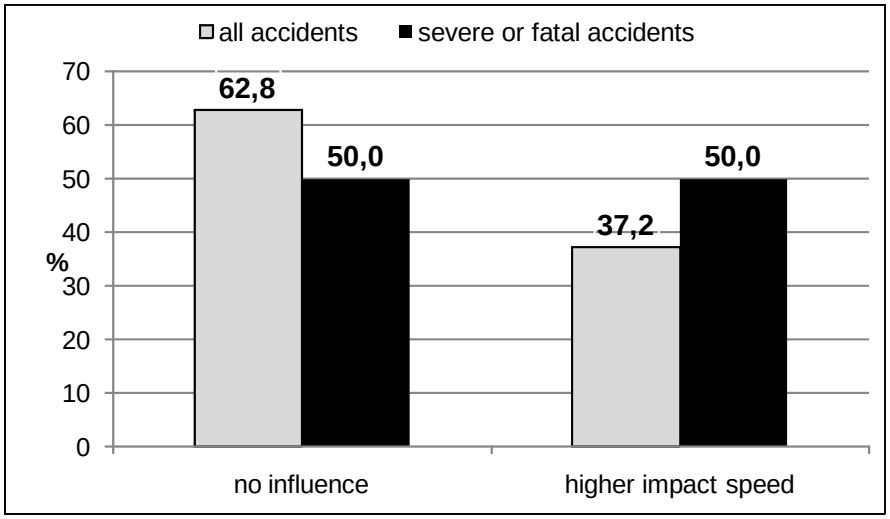

Figure 5 Possible Effects of grip value **minus** 10 respectively 15% assumption

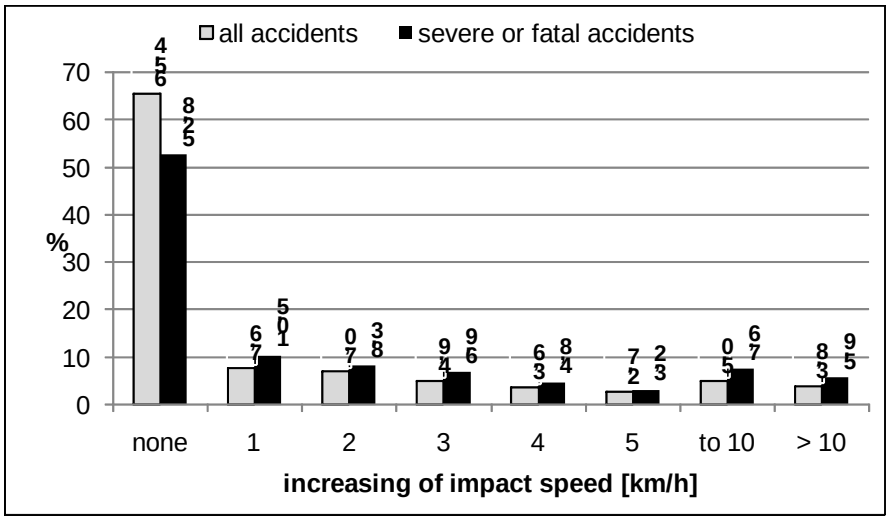

Figure 6 Possible Effects of grip value **minus** 10 respectively 15% on the Collision Speed

After all, with reduced grip values of 10/15%, at least 5% of the accidents would have occurred at velocities of 5 to 10 km/h higher and even 3.8% of the accidents at speeds of more than 10 km/h above the one they really occurred (Figure 6).

Using a cumulative representation covering all velocities of all accident cases the effects of changed grip values plus minus 10/15% is to be expected graphically.

In cases of a lowered grip value a significant increase of the collision speed over the whole velocity area would occur. With higher grip values a significant reduction in particular in lower velocity ranges of up to 35 km/h can be established. This is due to the fact that a positive effect can be expected particularly, if an increased braking period or an increased braking distance were present, which also resulted in an increased reduction of the speed and thus in a lower collision speed.

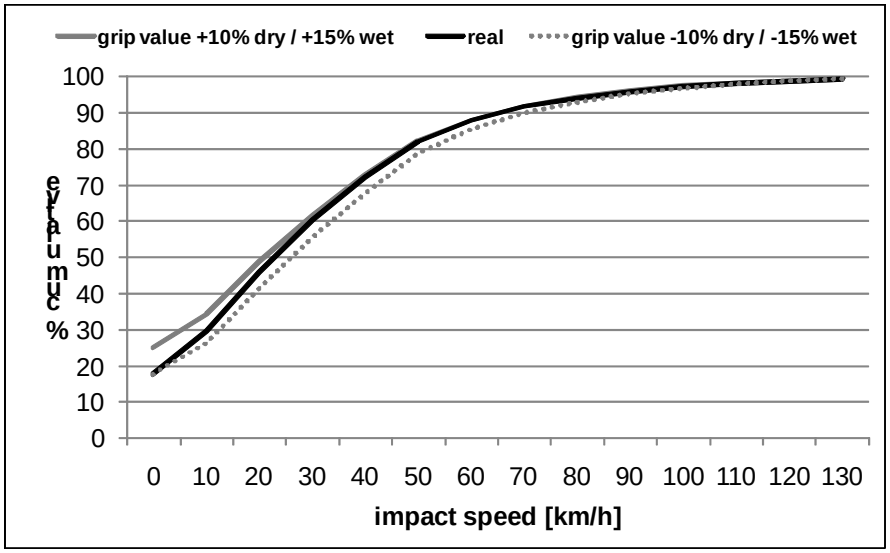

Figure 7 Possible Effects of grip value **plus minus** 10 respectively 15% assumption on the collision speeds of the cars

INFLUENCE OF SHORTER-LONGER BRAKING ON THE INJURY SEVERITY

When analyzing the accidents in terms of a potential for an improved friction coefficient between tire and road surface, an influence of the injury severity owing to the occupants of cars and external collision partners, such as pedestrians, bicyclists and motorcycle riders can be expected besides the avoidance of accidents and the reduction of the collision speed.

The influence of the collision speed to the resulting injury severity can be seen in Figure 8.

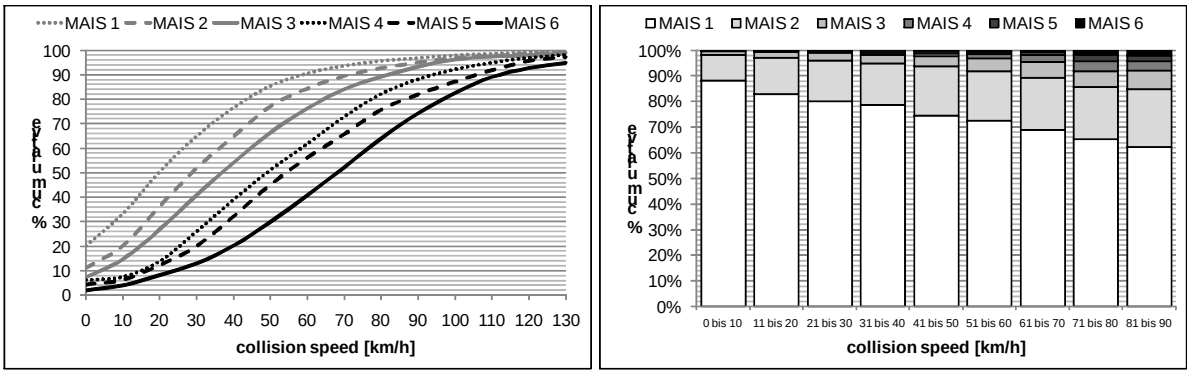

Figure 8 Cumulative frequency of collision speed for each injury severity grade and distribution of injury severity grade for each collision speed

To analyze the influence of the collision speed on the degree of injury severity MAIS, an ordinal logistic regression was conducted.

For the analysis of the injury outcome related to different accident severities the method of Odds Rations was used.

Measure of the odds of an event happening in one group compared to the odds of the same event happening in another group seems to be the best process for assessment. In scientific research, odds ratios are most often used in case-control (backward looking) studies to find out if being exposed to a certain substance or other factor increases the risk (Hosmer, 2000). For example, Odds are given the probability of an occurrence of an event. The odd-ratio is describing the relationship of odds for the assessment of the influence pattern. Calculate the odds of exposure in both groups and then compare the odds, the odds ratio

of 1 means that both groups had the same odds of exposure and, therefore, the exposure probably does not increase the risk of the event. An odds ratio of greater than 1 means that the exposure may increase the risk, and an odds ratio of less 1 means that the exposure may reduce the risk.
To evaluate the influence of the collision speed on the injury severity degree MAIS an ordinal logistic regression analysis was applied; the MAIS entered as ordered categorical outcome and collision speed as covariate in the model. The exponentiated estimated coefficients of the ordinal logistic regression can be interpreted as estimated odds ratios. In the ordinal logistic case, it is the ratio, given a one-unit increase in the covariate, of the odds of being in a higher rather than a lower category.
Additional ordered logistic regression analyses were performed for the distinct types of collision partners. The results of the analyses are presented in table 2: odds ratios with 95% confidence intervals and the significance levels (p-values) are stated. The analyses were performed with SAS Version 9.2.

It was the objective of this analysis to estimate the probability for the change in injury severity of a person as a function of the changed collision speed of the motorcar by different friction situations. With the method of odd-ratio the mathematical probability or chance is given, that an observed event will and will not happened. The results of the analysis were all highly significant and can be taken from the following table 2.

Table 2 Influence (Odds-Ratios) to Injury Severity MAIS by 1km/h speed change

	MAIS			
	vk +1 km/h		vk -1 km/h	
	estimate	p	estimate	p
pedestrian	1,058	<0,0001	0,945	<0,0001
bicyclist	1,052	<0,0001	0,951	<0,0001
motor cyclist	1,029	<0,0001	0,972	<0,0001
motorcar	1,018	<0,0001	0,982	<0,0001
truck	1,010	0,0116	0,990	0,0116
object	1,013	<0,0001	0,987	<0,0001
total	1,018	<0,0001	0,982	<0,0001

These results imply i.e. for pedestrians that the odds to have a higher category of MAIS increase by a factor of 1.058 if the collision speed increases for 1 km/h. If the collision speed increases for 10 km/h the odds ratio can be calculated as $1.058^{10} = 1.764$. This estimate implies a 76.4 percent increase in the odds of a higher category of MAIS per 10 km/h increase in collision speed.
For decreasing collision speed the odds ratios can be calculated as 1/1.058 = 0.945 for 1km/h resp. $1/1.058^{10} = 0.567$ for 10 km/h. This indicates that there is a 43.3% reduction in the odds of a higher category per 10 km/h decrease in collision speed. To be able to isolate the influence of the differing collision speeds due to different friction coefficients between tire and road surface on the injury severity in the course of this study, for every case the resulting change in collision speed and the resulting estimation of risk for a changed MAIS were calculated according to the formula:

$$\text{case based virtual risk value} = \text{estimation of risk}^{\text{change of impact speed}}$$

For an improved comparability the degrees of injury severity regarding the AIS classification were used by 6 severity grades. This method of assessment considered that with increasing collision speed the injury severity also increases and that with decreasing collision speed the injury severity MAIS also turns out to be lower. This could be confirmed by the estimated risk value. With this assumption the changes in injury severity could be calculated.

The estimation is the chance to change injury severity grade to next level. With this method a new distribution of injury severity grades could be determined, Figure 9 is shown the results of changes on the distribution of injury severity grades MAIS for all accidents of motorcars. With plus 10/15% increase of grip value a higher number of uninjured people would be registered, that means these people will move from injured to uninjured level, but in case that here only accidents with injured person are considered, no attention will give on that.

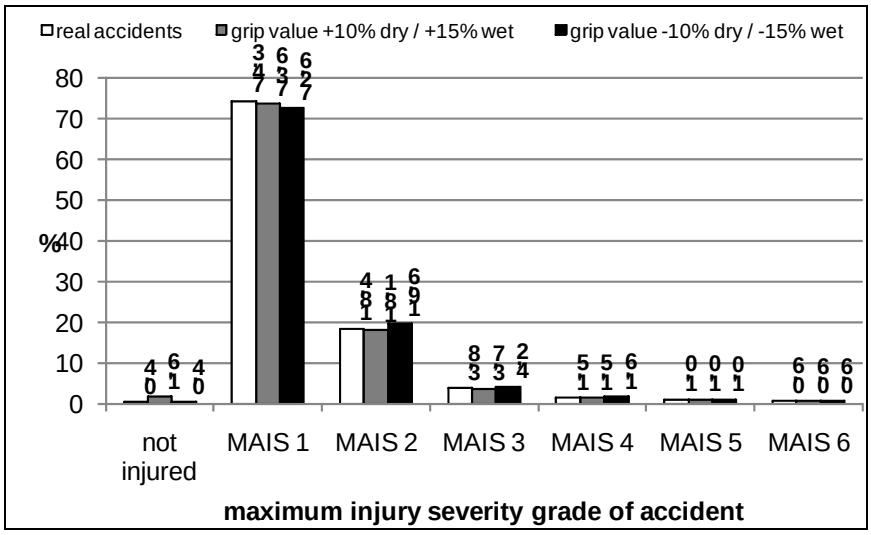

Figure 9 Distribution of Accident Severity MAIS with the Estimation of change of grip values

The differences of changes on the different injury severity could be pointed out in Figure 10. MAIS 1 injured persons will be reduced by 2.3%, MAIS 2 by minus 2%, MAIS 3 by minus 1.2%, MAIS 4 by minus 1.8%, MAIS 5 by minus 0.5% und the most severe and fatal injured victims reduced by minus 4.5%.

In contrast to that mostly higher percentages could be calculated for changes in lower grip values, i.e. there would be an increase of 10.9% MAIS 3 and 6.3% most severe and fatal victims.

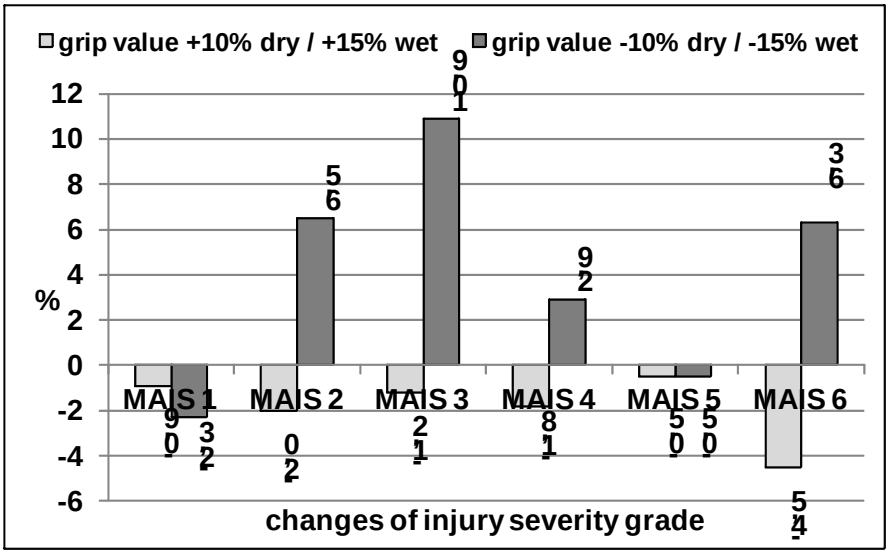

Figure 10 Differences of Injury Severity Grades with the Estimation of change of grip values

With these new calculated changes in injury severity by changes of grip values the following results can be pointed out if summarized MAIS into three groups, regarding the use of the official national statistics. Concerning the best comparison (Otte), these groups are: MAIS 0/1 in accordance with minor injured, MAIS 2-4 in accordance with severe injured and MAIS 5/6 in accordance with most severe and fatal were put in groups together. It can be seen, that changing the grip values by plus 10/15% more minor injured persons can be observed (Figure 10). The estimation is that using better tires about 2.0% of fatalities can be avoided and using lower grip values the number of fatalities will increase by 2.0% and more severe injured persons can be observed.

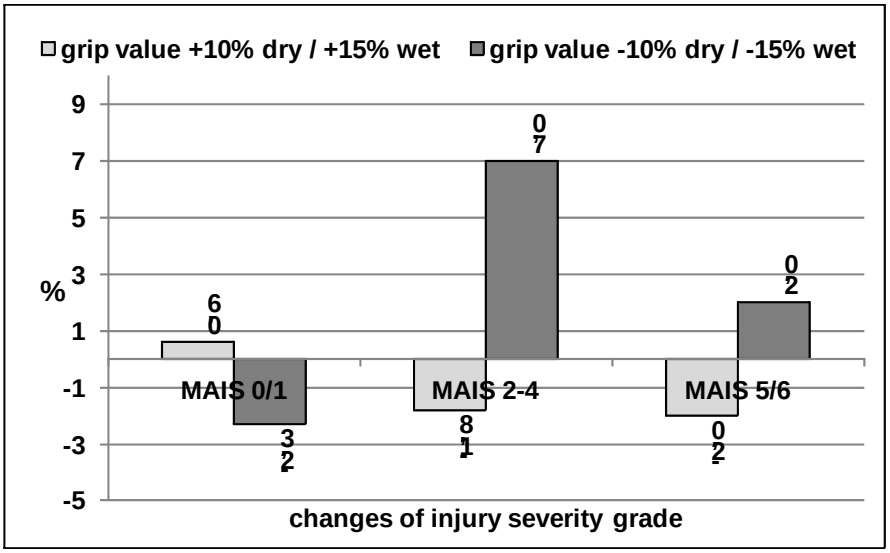

Figure 10 Differences of Injury Severity Grades by changing grip values **plus minus** 10/15%

INFLUENCE BY GRIP VALUE CHANGES FOR ACCIDENTS WITH DIFFERENT COLLISION PARTNERS

In the study the used methodology was adopted on the different accident samples of cars and their kinds of collisions.

Accidents of motorcars and trucks occurred in approximately 45% of the cases on junctions and interceptions and 43% on straight road sections. 44.7% of the car drivers stepped on the brake before the collision, thus the collision speeds were lower than the driving speeds. Especially on wet surfaces a particularly marked difference between driving and collision speeds distributions appeared. This demonstrates that the use of better grip would have prevented 2.2% of the accidents of motorcars with trucks (0.4% temporally, 1.8% spatially, for accidents resulting in most severely and fatally injured persons this percentage rises to 2.8% (0.3% temporally, 2.5% spatially), in 18.4% of the cases the collision speed would have been lower, in 25.3% for accidents resulting in most severely and fatally injured persons.

Accidents of motorcars and motorcycles occurred in approximately 60% of the cases on junctions and intersections. For moist or wet road surfaces the percentage of accidents in curves is higher (7.0%). Collisions between motorcars and motorcycles can be attributed to conflicts while turning off or into a road or crossing a road in more than 60% of the cases, with 15.3% of the cases being an accident type, in which a collision of a vehicle turning left with an oncoming vehicle driven straight ahead. It turned out that 4.1% of the accidents between motorcars and motorcycles could have been prevented if better grips of 10/15% had been used (0.4% temporally, 3.7% spatially). For accidents with most severely and fatally injured persons this percentage is 3.7% (0.2% temporally, 3.5% spatially), in 9.8% of the cases a lower collision speed can be assumed (12.1% for accidents with most severely/fatally injured persons).

Accidents of cars with objects, also called single-vehicle accidents, generally took place on the open road, for dry roads accidents on straight sections were most common at 54.7% and on moist or wet roads accidents in curves were the most frequent at 48.8%. 80% of the single-vehicle accidents of cars are driving accidents, of which the car running off the road 26.7% is the most frequent. Single-vehicle accidents of cars are typical accidents on country roads, which can be gleaned from the speed limit at the site of the accident, which was listed as 100 km/h for about 30% of the cases. The percentage of dry road surfaces for single-vehicle accidents of cars was remarkably low, in many cases, about 35%, the surface was wet, however, and at 10.6% it was also uncommonly frequently slippery owing to snow and ice. For 86% of all motorcars the brakes were applied before the object was struck, this is a particularly high percentage. The distribution between driving and collision speeds is most pronounced in these cases. On dry roads 80% of the driving speeds were located in a range of up to approx. 115 km/h, 80% of the collisions occurred at

speeds of up to 90 km/h. It turned out that the use of better grip could have prevented 4.1% of the accidents (4.1% spatially), for accidents with most severely or fatally injured persons there would still have been a spatial avoidance rate of 2.4%. There is no temporal avoidance for this type of collision. In particular for accidents of cars on straight stretches of the road, which are connected to collisions with objects, a high potential for an improved friction coefficient can be expected.

The following summarized assessment of avoidance by better or lower grips plus minus 10% on dry and 15% on wet roads could be calculated within this study (Tables 3 and 4).

Table 3 Influence on impact speed by grip changes of **plus** 10/15% for Different Collision Partners

collision partner	decreasing impact speed
other motorcar	25,3%
truck	18,4%
motorcycle	9,8%
bicycle	25,5%
pedestrian	33,0%
object	84,8%
total	**29,6%**

Table 4 Influence on impact speed by grip changes of **minus** 10/15% for Different Collision Partners

collision partner	increasing of impact speed
other motorcar	29,6%
truck	21,5%
motor cycle	15,4%
bicycle	34,4%
pedestrian	45,4%
object	99,7%
total	**37,2%**

Using better grip could decrease the portion of most severe or fatal injured persons in average by 2.0% (Table 5) and reduce the number of accidents with severe injured persons by 1.8% in average. The highest reduction rates for severe as well as most severe and fatal injury severities could be calculated for pedestrians and bicyclists.

Table 5 Avoidance and Injury Reduction by Using **Better Grips** for Different Collision Partners

collision partner	accident avoidable	severe injured persons	most severe or fatal injured persons
other motorcar	3,0%	-1,6%	-1,8%
truck	2,2%	-0,7%	-2,5%
motor cycle	4,1%	-0,5%	-
bicycle	6,6%	-3,2%	-3,7%
pedestrian	9,9%	-2,9%	-5,3%
object	4,1%	-3,1%	-0,7%
total	**5,0%**	**-1,8%**	**-2,0%**

Using lower grip would increase the number of accidents with most severe or fatal injured persons by 2.0% (Table 6). The number of accidents with severe injured persons would increase by 7.0%. The highest rates of increasing injury severity could be established for pedestrians and bicyclists again.

Table 6 Injury reduction by using **lower grip** to accident severity for different kinds of collisions

collision partner	severe injured persons	most severe or fatal injured persons
other motorcar	+8,2%	+1,8%
truck	+2,6%	+2,5%
motorcycle	+2,5%	-
bicycle	+12,3%	+3,3%
pedestrian	+9,6%	+8,7%
object	+9,6%	+0,4%
total	**+7,0%**	**+2,0%**

SUMMARY AND CONCLUSION

For this study a representative sample of 11 400 reconstructed traffic accidents from GIDAS (German In-Depth-accident -Study) was used to analyze the effect of having a 10% better or lower friction coefficient on braking of a car in an road accident event under dry conditions and 15% under wet conditions. These accidents had been collected and analyzed under a statistical random procedure and weighting of the dataset regarding the official reported accidents of the German road statistics. The objective of the study was to analyze the potential of an improved friction coefficient between tires and road surface for its influence on the course of the accident avoidance and injury reduction possibilities. The expectation is a reduced braking distance and a resulting lower collision speed for an optimized brake action.
It can be stated for the study, that the assessment of the effect of better or lesser grip is very difficult and the assumption and methodology used for this study could be interpretated with some critical look. In praxis there are on one hand different tires with different performance capacity on the market, on the other hand in life duration of a tire the grip value is reduce by use. Even there will be a mixture of good and worst grip values in the fleet of cars on the road, a scientific question was tried to answer within this study; what could be reached by better grip values regarding the accident outcome of injury severity.

Such scientific task of the study requires a very detailed accident analysis of comprehensive information from the accident field including a determination of the brake distance, the prior driven velocities and also the impact speed, but also a representative description of the accident scenarios occurring in traffic. To this end accident compilations collected on site are suitable, for these the data of GIDAS (German In-Depth-Accident-Study) could be used for this purpose. Another critical argument for the study has to be the fact that so-called near-accidents cannot be deduced from the GIDAS data. This way the two types of accidents show that very frequently the driver had lost control of his car before he hit the object. It can be expected that similar driving situations occur frequently and that the controllability of the vehicle depends particularly on the grip values. The analyses have yielded, however, that for reduced grip the velocity would be diminished more slowly while braking and thus result in a higher collision speed. Also the method used for the assessment of the change in the resulted injury severity should be discussed with some doubt, but the authors could be found this as the best for the study approach.

In general the consequences of changes of the grip values to the bake distances are relatively small and may be comparable to the magnitude of the uncertainty in the estimation of collision speed following in upper and lower bounds of each estimation of speed. Such bounds were not considered here. Also not considered is the effect of grip for sliding on the road. To get better comparable results only braking was used for the assessment of the study. By specifying the change of the mean deceleration value by X - percent the collision speed in each case was recalculated and the avoidance of every accident was determined followed in a virtual collision speed, that could be correlated to the assumption of injury severity AIS. The influence of the "X% criterion" has been presented in this study, for which the changes for a braking deceleration, based on the “mean deceleration value” were analyzed for an increase or decrease by X%. The used percentage on better and lesser grip was oriented on the assessment of a tire manufacture CONTINENTAL based on scientific experimental results of tires on the market (Wies, 2006; TCS, 2009) for dry and wet road by an assumption of 10 respectively 15%. With this the study got an scientific ap-

proach and opens the possibility for self interpretation of results, not depending on real existing tire performances.

The study analyzed only reconstructed cases, that means a large part of the sample was not used (17052 accidents in total, 13653 reconstructed with 11400 accidents with a car).The comparison of distributions as collision partners, injury severity and accident types are shown similarity, therefore it could be stated no bias for the current study.

This study resulted in a potential of better grip values between tires and road surface, which can definitely reduce collision speeds of cars in 30% of all traffic accidents resulting in personal damage.

5% of the accidents would even have been completely avoidable by using better grips of plus 10% on dry road conditions and plus 15% on wet road conditions. In contrast for lower grip values the collision speed would increase in 37% of the cases.

The results of benefit potential (given as a percentage) for a change in friction coefficient for better or lowered grips permit an assessment of the accident and injury situation occurring in real life:

MAIS 1 injured persons will be reduced by 2.3%, MAIS 2 by minus 2%, MAIS 3 by minus 1.2%, MAIS 4 by minus 1.8%, MAIS 5 by minus 0.5% und the most severe and fatal injured victims reduced by minus 4.5%. In contrast to that mostly higher percentages could be calculated for lower grips, i.e. there would be an increase of 6.3% most severe and fatal victims for lowered friction values of 10 respectively 15%.

Using better grips the portion of most severe or fatal injured persons could decrease in average by 2.0% and reduce the number of accidents with severe injured persons by 1.8% in average. The highest reduction rates for severe as well as most severe and fatal injury severities could be calculated for pedestrians and bicyclists. Having lower grip values of minus 10 respectively 15% in the accident scenario an increase of the number of accidents with most severe or fatal injured persons can be assumed by 2.0%. The number of accidents with severe injured persons would increase by 7.0%. The highest rates of increasing injury severity could be established for pedestrians and bicyclists again.

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