

Title: Did a higher distribution of pedelecs results in more severe accidents in Germany?

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Motivation and approach

There is a new trend in Europe and especially in Germany by the increased use of electric bicycles recently. This new vehicle category (includes pedelec, speed-pedelec, E-bikes) enables driving with electrical engine support [1].

In particular, the class of electrical bicycle with electrical support up to 25kph and maximum power of 250W (pedelecs) have the highest market share of approximately 95% [2]. This is impressively illustrated for Germany by the determined sales volume of the last years. At least in Germany up to 400,000 units were sold in 2013.

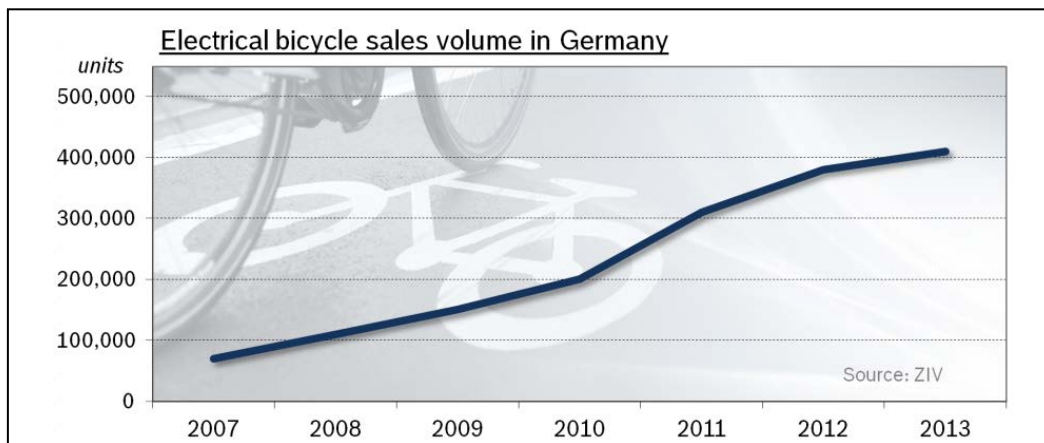


Fig. 1: Trend of electrical bicycle sales in Germany [2]

Considering a higher penetration and traffic participation in future as a consequence thereof the number of accidents involving these new vehicle types (especially pedelecs) will also be influenced. Hence the question arises how and in which way will be the impact towards the traffic safety in Germany in near future?

Did a higher distribution of pedelecs results in more severe accidents in Germany?

At this time it isn't easy to answer this question with available facts. Existing completed studies usually show only consequences of single events with involved e-bikes for example the result of collision between passenger car and pedelec with the maximum supported speed (25kph in case of a pedelec and 45kph in case of a speed-pedelec) [5]. A completed study which analyzed pedelec accidents of German in-Depth Accident Study (GIDAS) Database in detail gives first results regarding pedelecs in real accident situations. A small number of pedelec accidents (sample size of $n=30$) were available for the study and analysed. As result, no higher frequent occurrence of serious injuries in comparison with bicycle accidents was found [7].

Aim of the following described study, is to estimate with a pessimistic approach the impact of pedelecs (assumed higher speed than bicycles) towards the traffic accidents severity in Germany for

different penetration rates. A change in the traffic accident situation is not part of this study due to the fact that the influence of the rider behavior cannot be estimated at this point of time. The common assumption is, that the usage of pedelecs and the driving behavior of their riders are different to conventional bicycles. This still has to be verified by more scientific investigations which should also include the behavior of other road users in interaction with pedelecs [8].

Till end of year 2013 no official accident statistics regarding electrical supported bicycles are available. For 2014 the new vehicle class pedelec is defined and will be registered in the official accident statistics in Germany. This makes an analysis regarding the accident situation of pedelecs possible in future. At this time, no reliable figures about the level of possible impact to accident situations are available but a first approach could be to analyze the traffic accident situations involving conventional bicycles with comprehensible assumptions respect to pedelecs.

Status

According to official statistics of 2012 [3] 74,961 accidents with casualties and bicycle involvement occurred. 406 users of bicycles were fatal, 13,840 riders were severely and 60,423 slightly injured. In about 41% of accidents with bicycle involvement (police reported, accident with casualties), the cyclist is the main causer. Approximately 83% of registered accidents with casualties and involved bicycles occur at daylight respectively at dry road conditions. Major registered faults within this category of bicycle riders in 2012 were identified as “wrong using road infrastructure” with almost 24% and "other driver's fault" with a share of 30%.

More information about the accident situation involving bicycles are not available in official statistics. Therefore an in-depth-analysis was done. The analysis of the GIDAS database¹ confirmed the interpretation of this official statistics by using the detailed specification of accident types. It is seen that the most common accident type are conflicts while crossing with a share of approximately 44% of these registered accidents. In addition 17% are characterized as cornering conflicts and 10% as accidents in longitudinal traffic. This is shown in Fig. 2.

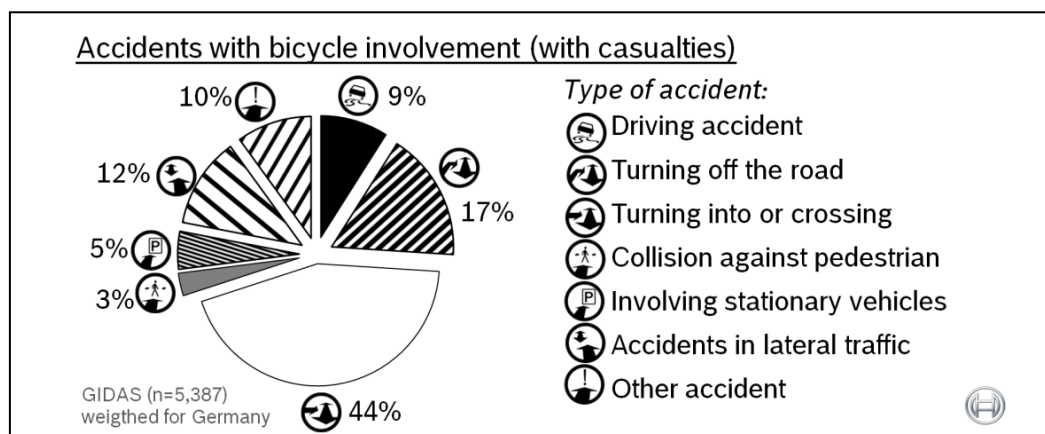


Fig. 2: Type of Accident, Accidents with bicycle involvement and casualties [4]

It is evident from Fig. 3, the highest share of accident causing situations with bicycle involvement and casualties is the accident type “Intersection, privileged cyclists from right on bicycle path” (but contrary direction of travel) coded as 342 with approximately 16%. Within this category the cyclists which used (often irregularly) the pedestrian walkways were neglected.

¹ 5,387 accidents with bicycle involvement – weighed for Germany

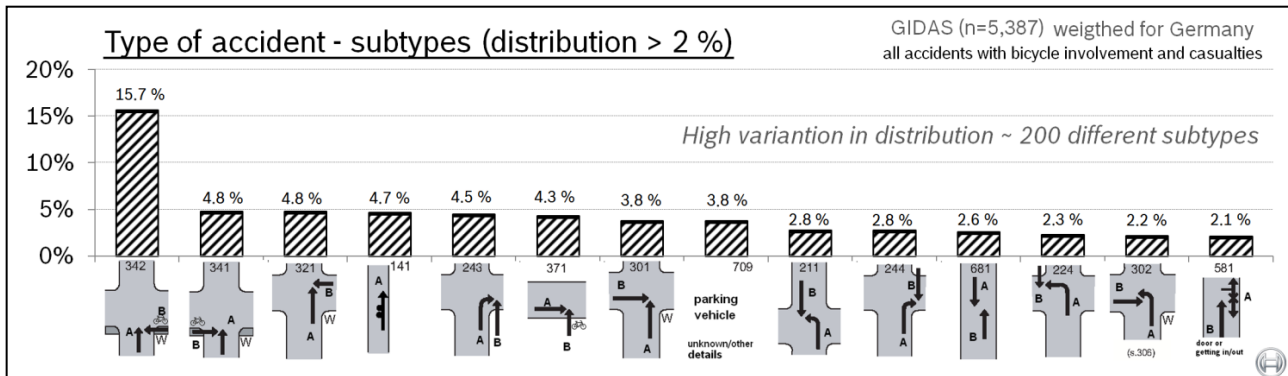


Fig. 3: Type of accident, subtypes with distribution greater than 2% [4][6]

Further on in 63% of all GIDAS accidents with bicycle involvement the opponent was a passenger car in the first collision. Bicycle to bicycle (11%) collision and direct contact with ground (12%) are also documented as first collision.

Research method

It is assumed that the general behavior of pedelec² user is similar to user of conventional bicycles. This is justified with the fact that a "normal" cyclist is able to reach nearly the same driving performance like a user of a pedelec if some more muscle power is considered. In particularly the maximum supported speed of a pedelec 25kph is reachable for a bicyclist without electrical support.

One intension of the study is, to show in how many situations an electrical support of bicycle has no influence to the sequence of accident events. Basis of the study are the in GIDAS database available accidents involving conventional bicycles. These accidents have been modified by a fictitious electrical engine support and thereby possible increasing speed. Afterwards the modified (pedelec) accidents have been compared with the original bicycle accident. The following assumptions were made in this individual case study:

- For Pedelec, the original speed of the bicycle (if possible) is increased by 10kph max as a pessimistic approach. The increasing of speed is only done in cases where this is possible due to the traffic situation.
- No change in precise positioning after recalculating of velocities (same collision point). The main reason for this assumption is the fact that in some cases the speed increase in initial situation results in a shift of the contact point. This means some collisions would not happened with a higher speed of pedelecs and on the other hand some former critical situations without collision (no accident – not in database) would result in an accident.

² Class 25kph, 250W only

Following basic assumptions are used for the analysis regarding pedelecs and their influence (possible change) in accident statistics of Germany:

- The distribution of accident types / kinds of accidents remains unchanged.
At this point of time it is not possible to predict a change in driving behavior of pedelec users. Whether there will be a shift in the distribution of accident types, can only be clarified by an analysis of a representative number of real accidents with pedelec involvement. This will probably be possible with the introduction of the new class of vehicle in the official accident statistics. Due to the fact pedelecs are very similar to conventional bicycles, the assumption no change in distribution of accident types is chosen.
- The results regarding injury risk and projected total number of casualties for Germany are calculated for 5%, 10% share of pedelecs of all bicycles.
- Underreporting of single accidents is considered.
Some current bicycle accident studies (e.g. in [9]) show that in Germany a number of underreported accidents (not in official statistics) with bicycle involved exists. In particular, this relates to bicycle accidents with injured bicyclists without property damage, for example a fall down or collision with a fixed object. These accidents are not often reported to the police and if necessary the involved bicyclists arrange the medical treatment by themselves (usually in case of minor injuries only). Here the underreported bicycle accidents (with casualties) are considered with a double weighting of bicycle accident without second participant (single-vehicle accidents).

To answer the question, raised as intention of the study, it is necessary to examine each individual accidents in the database. The analysis of all accidents is not possible due to the high number of relevant accidents. The for the study needed single-case analysis is done with 522 bicycle accidents in GIDAS. This chosen subsample includes all bicycle accidents in GIDAS in the year of 2009 (latest available complete year). The evaluation of a complete year ensures the consideration of different user behavior with different weather conditions, days of the week and seasonal issues. The preliminary analysis (distribution accident types, injury severity in terms of speed) was done with the maximum number of cases in GIDAS (2001-2012). Further on it was ensured that the accident type distribution belongs to the official statistics therefore a representative GIDAS subsample was analyzed. Fig. 4 gives an overview of the analysis in principal.

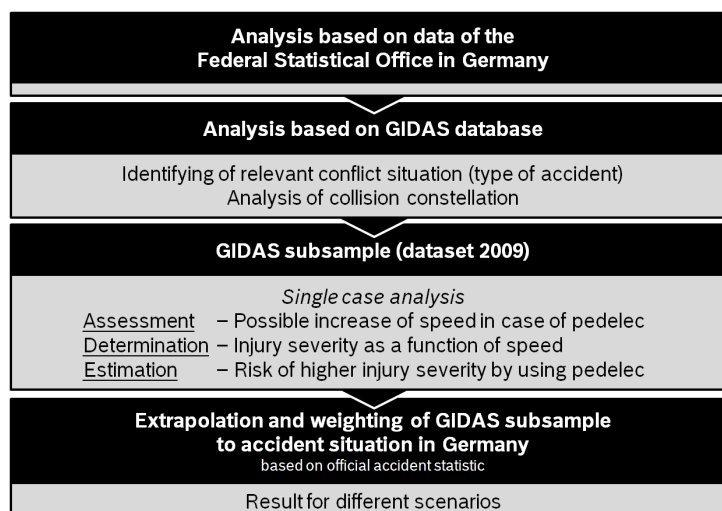


Fig. 4: Methodology of the study

Results

Apart from other accident related factors the important parameter is collision or initial speed of the bicycle which links directly to the severity. In single-case analysis it is evaluated whether a higher speed of pedelec instead of bicycle is possible. Main factors are the traffic situation and road condition at the accident scene. For this purpose, the detailed reconstruction data including scaled sketch, accident descriptions and pictures were used.

Taking into account that the electrical support in case of a pedelec is given up to 25kph one major result is shown in Fig. 5.

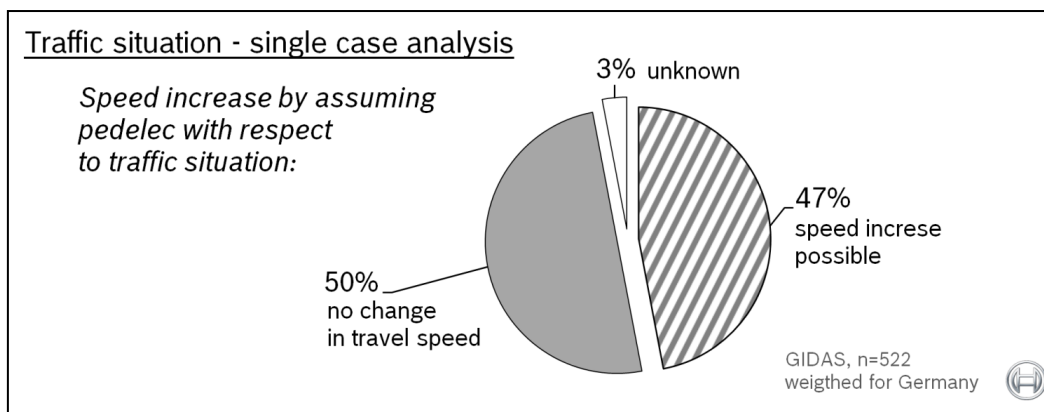


Fig. 5: Single case analysis of traffic situation by assuming pedelec instead of bicycle [4]

In around half of the registered bicycle accidents, a higher initial/travel speed is not possible hence a change is not assumed. This result is mainly caused by driving situation and the fact that a higher travel speed with respect to the situation is not possible. These situations are e.g. while turning into a road, driving down the hill and while waiting. Detailed reasons are shown in Fig. 6.

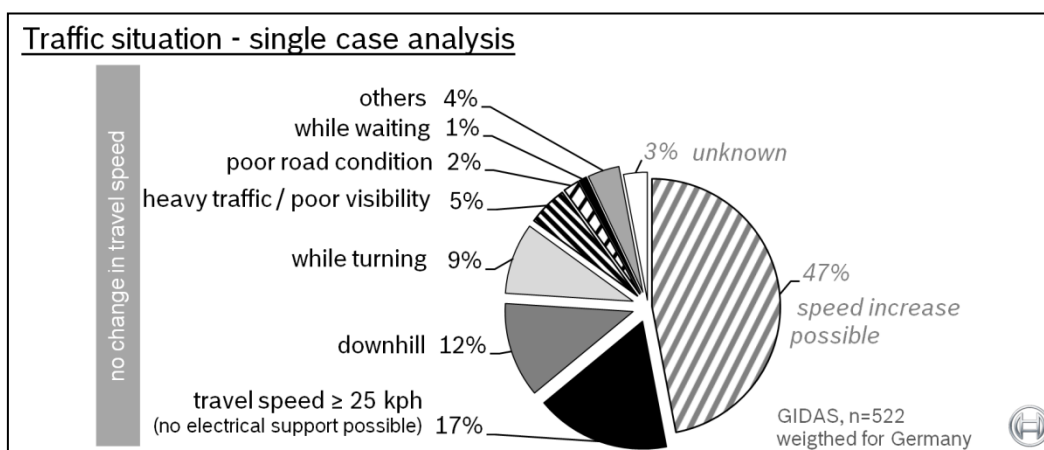


Fig. 6: Single case analysis, Reasons for no change in travel speed [4]

A higher speed is therefore assumed while driving on free roads (45%) or while a support is given during hill driving (2%).

In addition to the traffic situation with possible increased speed, the collision situation itself has influence to the injury consequences of cyclists. For the consideration of these crash details all accidents are divided in four groups describing the collision situation according to the following definition:

- Group 1: Fall down or collision with an object (mainly single-vehicle accidents)
- Group 2: Collision with other vulnerable road user (pedestrian, bicycle, motorcycle)
- Group 3: Bicycle hit a vehicle (car, truck or bus), bicycle frontal contact
- Group 4: Bicycle was hit by a vehicle (car, truck or bus), bicycle side or rear contact

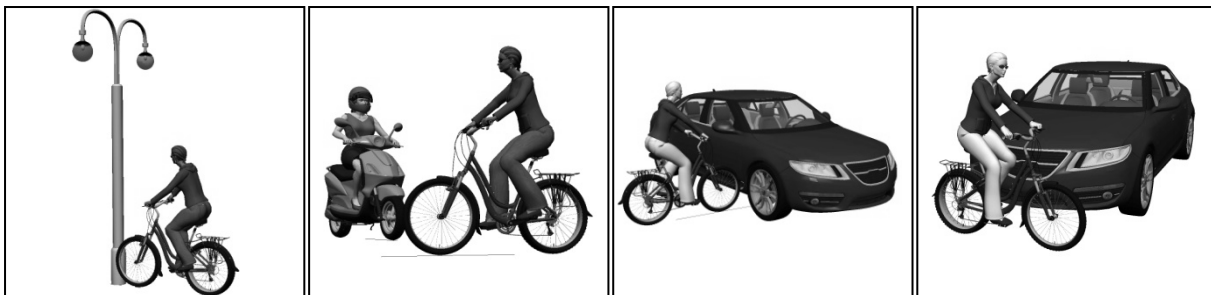


Fig. 7: Animated situations for Group 1 (left) to Group 4 (right)

The classification is done due to the fact that in Group 1-3 the speed of the cyclist (and therefore the pedelec) is more relevant for its severity. Contrary to the groups 1-3 in group 4 the speed and also the mass of the opponent are the main important factors regarding the severity of cyclists. The initial speed of bicycle has only a minor influence.

The following collision situation distribution is given (Fig. 8). Every third bicycle accident (32%) results in a contact against an object or fall down without another primary impact (Group 1). In a share of 13% a conflict between a bicycle and other vulnerable road user is given (Group 2). Further on in about 16% of all analyzed bicycle accidents, the cyclists hits another vehicle (car, truck or bus) with the bicycle front (Group 3).

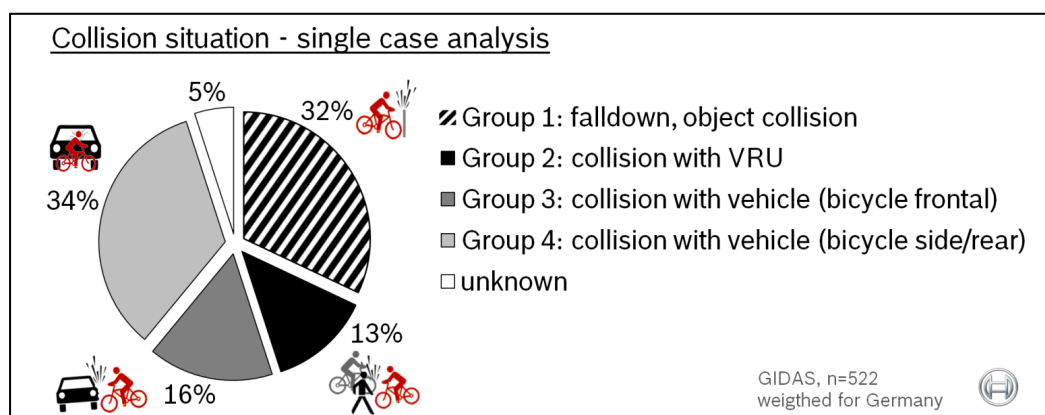


Fig. 8: Single case analysis, Collision situation [4]

The highest share of 34% is categorized in Group 4 whereas a vehicle (car, truck or bus) hits the side or the back of the bicycle. These accidents are characterized with a higher severity of the cyclists. In those accidents the bicycle speed can be neglected due to the fact that the collision speed of the motorized vehicles is the main contributing factor for the injuries at time of collision. Unfortunately, the mass of the vehicle is much higher compared to the bicycle. In another share of about 5% the accident details are unknown and therefore not considered in the analysis.

To determine the possible change in the severity of the current accident situation (number of severe injured persons), it is necessary to combine the results shown in Fig. 5/Fig. 6 with results shown in Fig. 8. Linking single case analysis regarding traffic situation with the collision situation results in a share of 27% of all accidents where a higher travel speed could be assumed. In other words in 68% of all relevant accidents, no higher risk of injury severity in case of using a pedelec is seen because of speed has no higher influence or a higher speed is not possible as result of the traffic situation. This distribution is shown in following Fig. 9. Only the collision situation of group 1, 2 and 3 with a possible speed increase have a higher risk in injury severity.

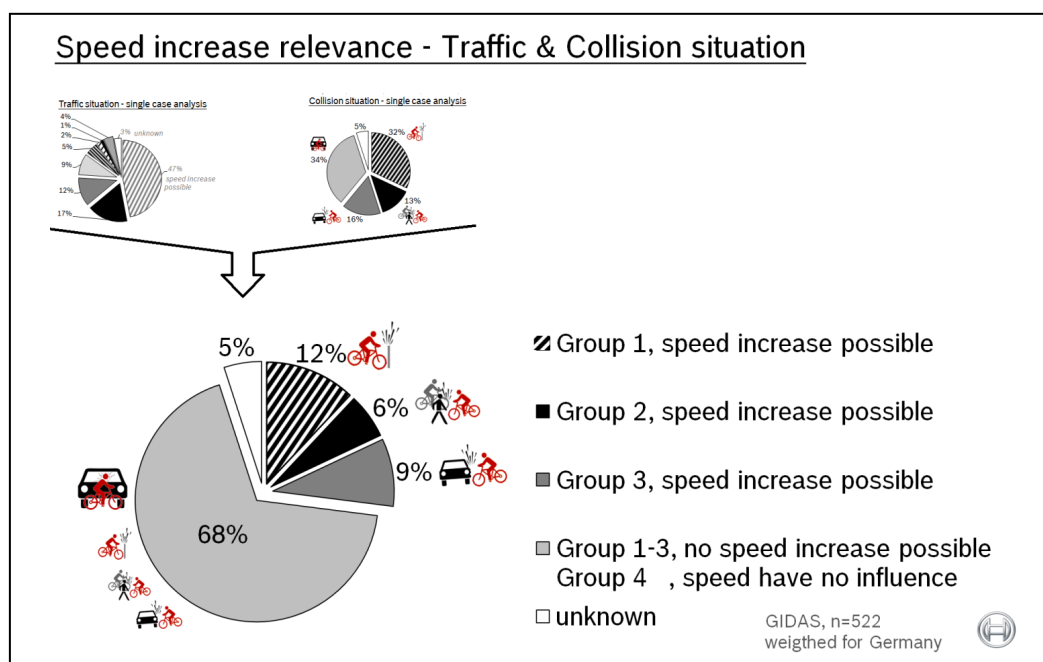


Fig. 9: Results of combination of traffic situation and collision situation [4]

To determine the possible influence to German accident situation, the injury severity was recalculated for each relevant GIDAS accident. The results are weighted and projected to Germany. The categories of injury severity was determined in the two groups (“slightly injured” and “severe/fatal injured”). Due to the fact of low count of relevant cases with fatal injured cyclists in GIDAS a further differentiation in “severe injured” and “killed” is not useful. The analysis of injury severity with respect to collision speed was done for two age groups (younger bicyclists age <50, elderly bicyclists with age 50+).

The risk of being severe injured as a user of pedelec is recalculated for each relevant case as a function of speed (including max. 10kph speed increase), age and collision details. As a basis the determined³ functions of all bicycle accidents in GIDAS were used. The following figures show the distribution of severe injured bicyclists in percentage for each group of collision situation (Fig. 10, Fig. 11, Fig. 12 and Fig. 15).

³ Polynomial regression of all bicycle accident in same speed and age category

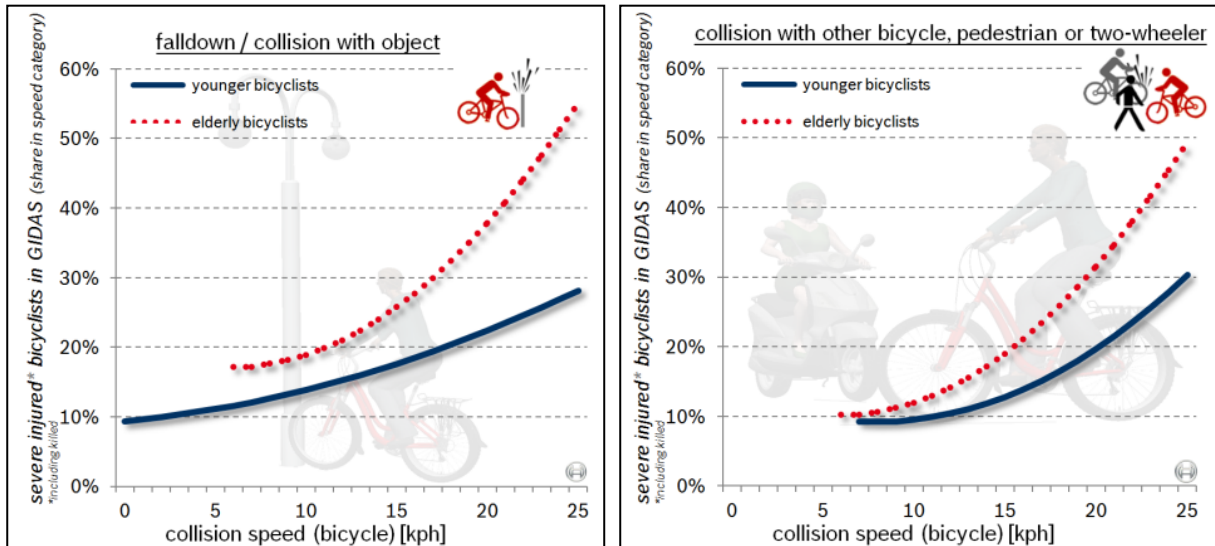


Fig. 10 (left): Dependence of injury severity to bicycle collision speed for collisions situation of group 1
 Fig. 11 (right): Dependence of injury severity to bicycle collision speed for collisions situation of group 2

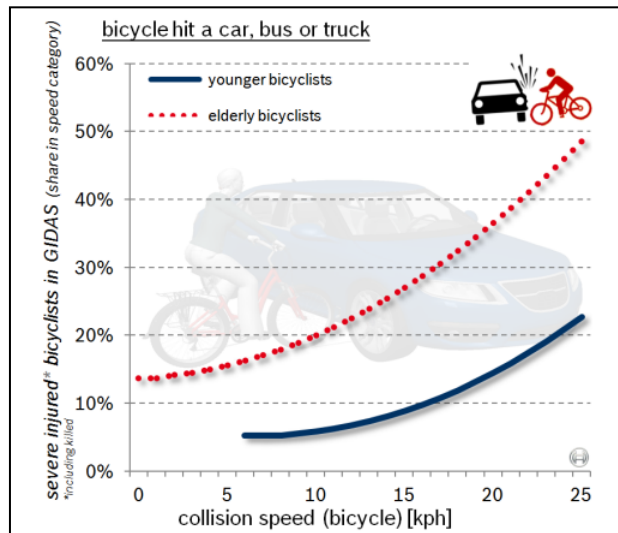


Fig. 12: Dependence of injury severity to bicycle collision speed for collisions situation of group 3

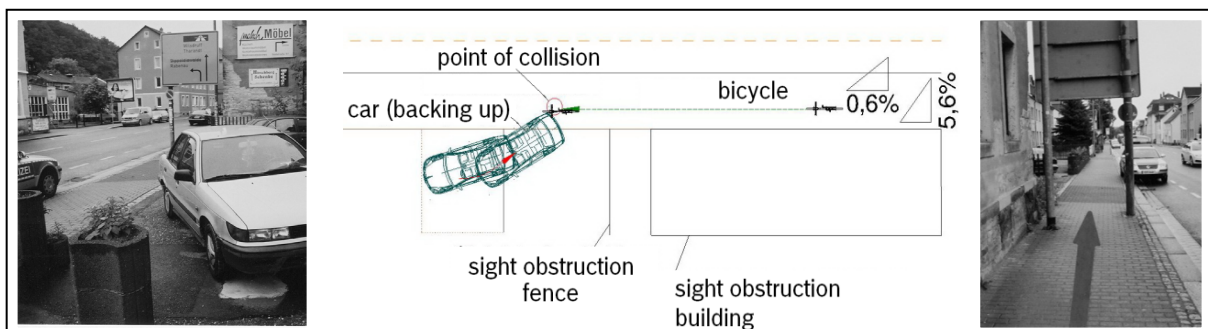


Fig. 13: Example case (1090437), collision situation of group 3 with possible speed increase

In the example-case (see Fig. 13) The bicycle hit a car which drove backwards. The collision point was located at the frontal tire of the bicycle. As result the case is dedicated to collision group 3 (Fig. 12). The reconstruction made by GIDAS experts calculated a speed of 12 kph (collision and travel speed, no braking reaction). In this study, with assumption of using a pedelec, the case was re-

calculated by using a increase collision speed (+ 10kmp) which results in a higher risk to be severe injured (Fig. 14).

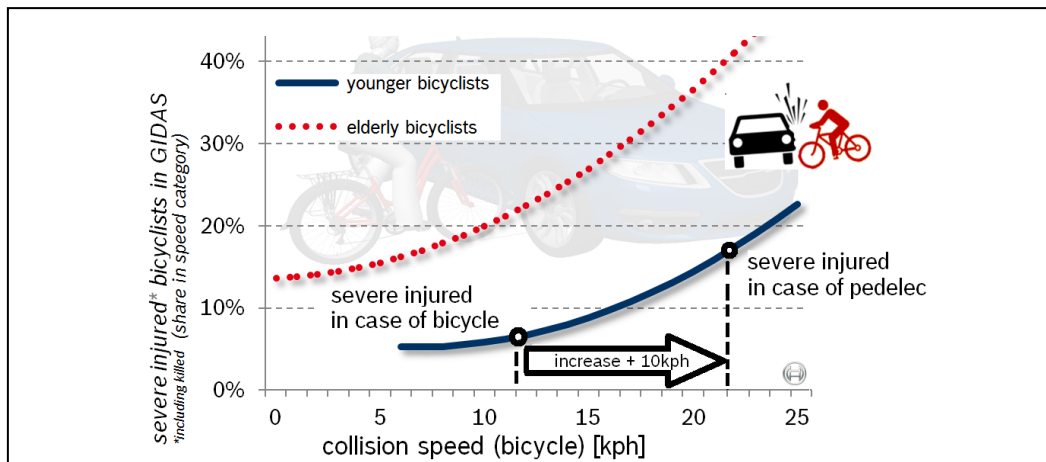


Fig. 14 : Change in injury severity by using pedelec instead of bicycle (Example)

In the case of using a pedelec the electrical support is only up to 25 km/h. In accident situations with higher speed the original injury severity is used. Also in all cases with collision situation of group 4 no changes were considered because the main factor is the collision speed of the motorized vehicle. The graph shows impressively the big influence of vehicle speed but has no influence regarding pedelecs.

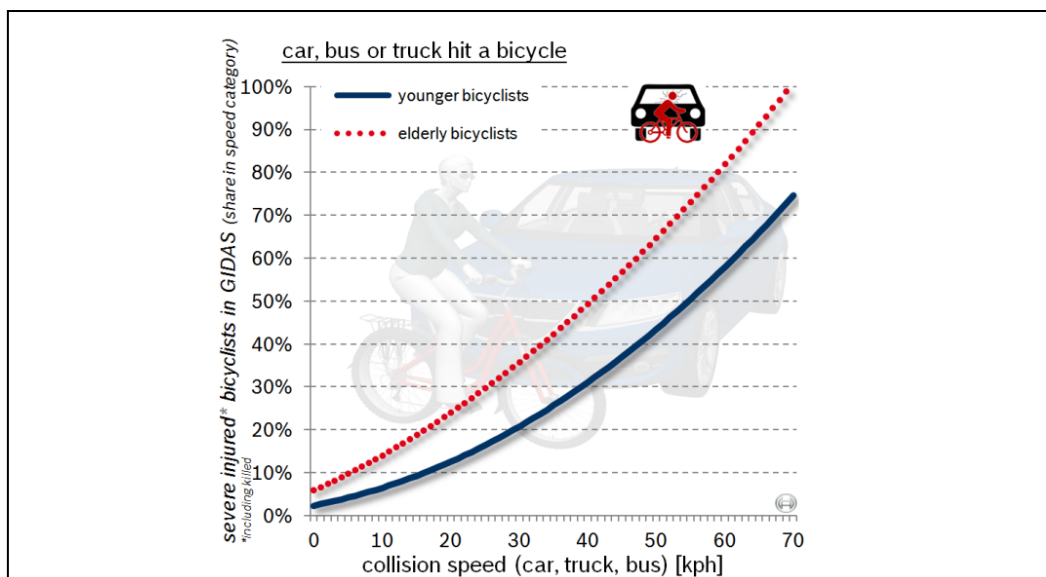


Fig. 15: Dependence of injury severity to vehicle collision speed for collisions situation of group 4

Conclusion

The study shows, in many real situations (68%, see Fig. 9) an electrical support of bicycle has no influence to the sequence of accident events. Taking into account a number of unreported "single bicycle accidents", the adoption of similar traffic behavior and similar age distribution, we determined a shift of 400 former slightly injured to seriously⁴ injured cyclists in Germany per year. In Overall this would be an increase of approximately 2.3% in case of 10% of pedelec penetration with the assumption of 10 kph speed increase (if possible).

Analysis of bicycle accidents with exploration to pedelecs shows contrary to popular opinion (strong increase in serious accidents) the number of higher injured cyclists rises only moderately (per year around 400 additional).

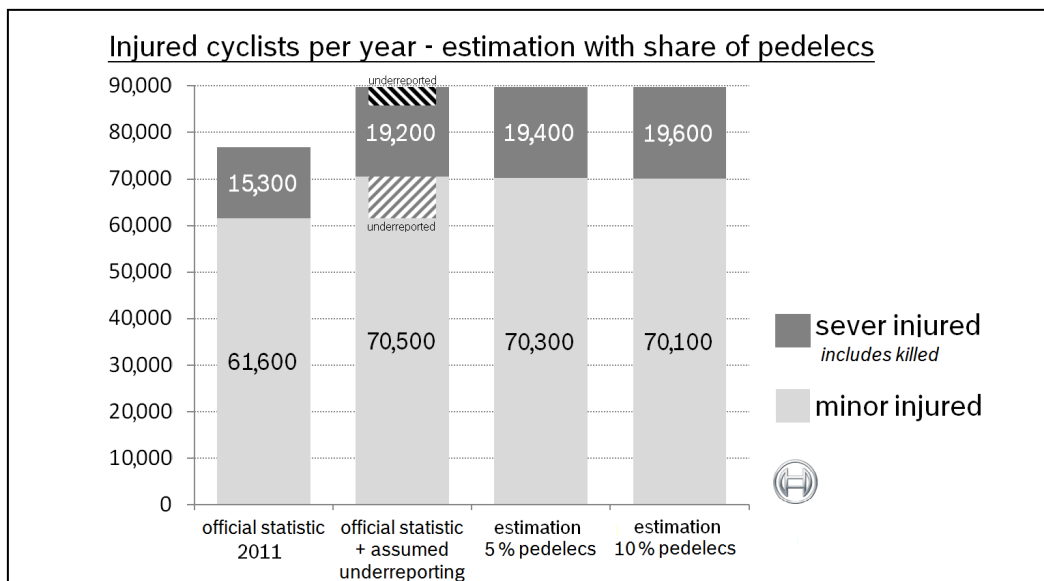


Fig. 16: Injured cyclists per yer with considering a share of pedelecs and underreported single accidents

For this study, a pessimistic approach by using speed increase of 10 kph was chosen, but first running natural driving studies predict a much lower increase in average speed of pedelecs [8]. The general opinion "the possibility of higher speed causes in large increase in severe accidents" is also not seen (Fig. 17) in the current existing official categories of two-wheeler (bicycle, moped (max. 25kph) and small motorcycles (max. 45kph).

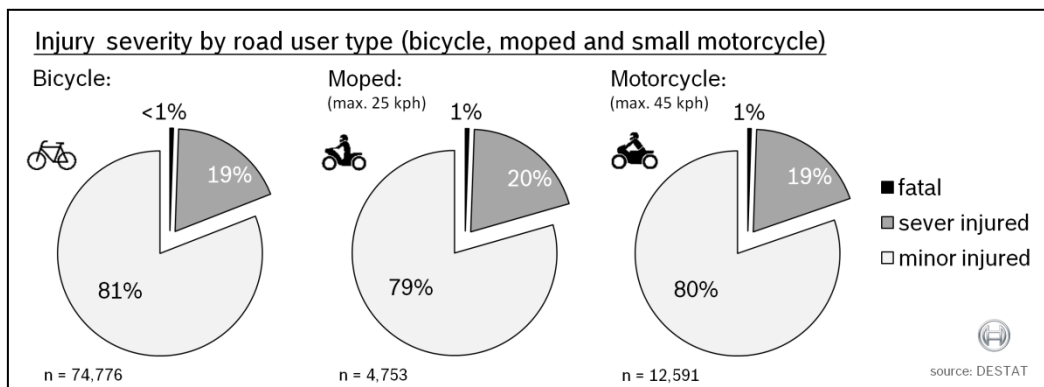


Fig. 17: Distribution of injury severity of different two-wheeler categories

⁴ In few cases also fatal

Reasons for the similarity of these vehicle classes may be the increasing safety awareness (e.g. use of protective clothing, better traffic discipline) and also a better visibility for other road users (noticeable driving behavior, no driving on walkway). In case of pedelec, the possible increase of severe injured cyclists could be compensated by other safety systems such as improved protective clothing, helmet or high quality brakes.

The hypothesis verbalized in the initial question “*Did a higher distribution of pedelecs results in more severe accidents in Germany?*” is not verified. This study shows, electrical support didn't result in higher collision speed in general. In many accident situations, the speed of pedelec have only a minor influence with respect to the accident severity. Further research focusing a possible change of driver behavior especially in new target groups (elderly people) is also needed.

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