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E-Bikes im Strassenverkehr – Sicherheitsanalyse

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4. E-bikes in road traffic – a safety analysis

E-bikes are an increasingly popular mode of transport, but they also pose accident risks. Their higher speeds in comparison with bicycles lead to longer braking distances and errors of judgement by other road users. The present research employs an accident analysis, a literature review, a rider survey and an experiment on estimating speed for a target-oriented assessment of the associated traffic safety issues.

The most important findings: according to official statistics, e-bike accidents are more serious than bicycle accidents, and serious single-vehicle accidents are more frequent than serious collisions. The differences in accident severity are primarily due to e-bike riders' higher age. Collisions involving seriously injured e-bike riders often occur at intersections and roundabouts when motorists fail to give right of way to e-bikes. One of the reasons is the underestimation of speed in pedal vehicles. The root cause analysis of serious single-vehicle accidents draws no definite conclusion. It is however clear that e-bike riders are aware of the higher speeds but possibly underestimate their consequences.

In-depth analyses of serious single-vehicle accidents and the systematic monitoring of e-bike-relevant parameters are therefore indicated, as are educational measures for motorists and new riders without prior cycling experience. Norms and existing traffic installations should be reviewed with respect to the specific requirements of e-bikes. And finally, the development of higher safety standards (automatic light activation, braking systems etc.) and the sale of e-bikes with high safety standards should be encouraged.

4. E-bikes in road traffic – a safety analysis

4.1 Introduction

The Swiss market for e-bikes has grown considerably in recent years, with some 150,000 e-bikes sold between 2011 and 2013 alone. Three quarters of these were slow e-bikes with pedal assistance up to 25 kph; a quarter were faster e-bikes with pedal assistance up to 45 kph. Older people are the principal users of e-bikes. In 2014, the average owner age was 53.5 years, although this is expected to drop slightly in the future. According to self-reported data, e-bike owners use their vehicles to travel around 2600 km per year.

Although e-bike riding offers many advantages such as flexibility and ecological and economic benefits, it also poses some dangers. Higher speeds in comparison with bicycles can result in longer braking distances or errors of judgement by other road users. The rise in e-bike sales and their exposure has coincided with a more than 70 % increase in the number of seriously or fatally injured e-bike riders on Swiss roads between 2011 and 2013. E-bikes are therefore increasingly becoming an issue for road safety.

The chapter **Accident analysis** describes the accident occurrence among e-bike riders on Swiss roads. The chapter **Literature review** shows the current state of research on e-bike rider safety. The chapter **Rider survey** introduces a survey exploring a variety of psychological factors influencing riding behaviour, followed by an **experiment** to determine how other road users estimate e-bike speeds.

4.2 Literature review

The literature review provides an overview of the current state of research on e-bikes and road safety. Since this is a new area of research, there is little scientific literature yet available. Moreover, the available findings should always be regarded in the context and against the background of the current user group. Some countries differ with respect to the kind (e.g. permitted maximum performance) and shares of the e-bike types used, and the main user group currently presents a rather high average age.

Studies on e-bike **riding speeds** in the neighbouring countries show that on average, e-bikes travel 1-4 kph (6-23 %) faster and a greater proportion of distances at higher speeds than bicycles. The speed variations observed in e-bike journeys are also larger. Faster speeds are observed mainly among fast e-bike types and younger riders. Riders tend to travel at slower speeds in challenging situations.

Studies on **behaviour** (riding and protective behaviour) have unequivocally shown that higher speeds lead to increased overtaking and more interactions with other road users. Whether this also increases the mental demands on the rider is not yet clear. No discrepancies were observed between e-bike and bicycle riders in terms of non-compliance with traffic regulations. The helmet-wearing rate in Switzerland however differs significantly (e-bike 69 %, bicycle 43 %).

Consulted studies demonstrated no difference in **accident frequency** between e-bike and bicycle users. Exposure-related data (e.g. performance, number of journeys) has remained largely disregarded to date. A study on conflict situations (data gathered

by video) found no disparities between the two kinds of vehicle in the number and type of critical situation, even when their performance was taken into account.

Research on **injury severity** – both in regards to the methodology (e.g. the considered accident severity, indicator of accident severity) and in regards to results – is not homogenous. When compared with cyclists, e-bike riders appear to be at greater risk of sustaining injuries requiring medical treatment. However, studies comparing only the degree of injury among casualties receiving medical treatment show no significant differences. Therefore no decisive conclusion can be drawn at the present time.

The literature review shows that **single-vehicle accidents** are the most significant **accident type** among e-bike riders. This accident type is observed somewhat less frequently among cyclists. It is so far unclear whether this finding is attributable to the differences in vehicle type or the user structure. In addition to speed, incorrect or heavy braking is probably a significant factor in single-vehicle accidents among e-bike riders.

Possible **technical problems** focus in particular on the retrofitting of conventional bicycles, specific braking and propulsion concepts, coasting and delayed start of the motor and an uneven weight distribution of the motor and battery.

Preliminary evidence suggests that e-bike riders are more vulnerable than cyclists to **errors of judgement by other road users.** One experiment demonstrated that motorists allow e-bikes shorter time gaps than bicycles to merge into the traffic flow.

4.3 Accident analysis

The overall set of data for police-reported accidents is currently the most reliable and detailed data source available. Although the accident analysis is subject to individual limitations (unreported incidents, on-scene assessment of certain accident characteristics), significant findings – which should to be examined in more detail – have emerged:

1. The rise in serious e-bike accidents between 2011 and 2013 correlates proportionally with the rise in the number of e-bikes on the road.
2. Police-reported accidents involving e-bikes are more serious than those involving bicycles. The main reason for this lies however in the age structure of the users rather than the vehicle type: e-bike riders are on average older and therefore more vulnerable than cyclists.
3. Serious accidents among e-bike riders are more often single-vehicle/skid-related than collision-related accidents.
4. In both absolute terms and in comparison with cyclists, e-bike riders have noticeably more not-at-fault accidents in roundabouts because merging motor vehicles fail to yield right of way.
5. In both absolute terms and in comparison with cyclists, e-bike riders have noticeably more not-at-fault accidents at intersections because motor vehicles merging from the right fail to yield right of way.

4.4 Rider survey

The objective of the survey conducted among e-bike riders in Switzerland was to determine the **psychological components** associated with **riding behaviour** and their respective characteristics. To this end, a model was developed with seven predictors for (self-reported) riding behaviour. The influence of

a number of control variables was also examined. All variables were recorded by questionnaire.

The assumption that e-bike riders themselves misjudge the risk factor of speed could not be confirmed. The majority of respondents are aware of the longer stopping distances and faster speeds of e-bikes and the potential for errors of judgement by other road users. The occurrence rate of single-vehicle accidents is somewhat misjudged. This knowledge, or lack of knowledge, does not appear to affect road behaviour.

Four psychological factors were significantly associated with self-reported riding behaviour: risk perception regarding e-bike speed as a risk, the feeling of being invulnerable and the subjective conviction of having the e-bike (in general) and its speed under control (as two separate factors). The directions of these associations were, at first glance, surprising in part – e-bike riders who are more aware of the speed risks report that they ride less carefully. Those who feel invulnerable, on the other hand, are more safety-oriented riders. It can therefore be assumed that these cognitions are more likely to be reflecting the displayed behaviour rather than controlling it.

Age, gender, frequency of e-bike use and previous riding experience on conventional bicycles – these four control variables were found to be significant predictors for self-reported riding behaviour. Women, older people, occasional e-bike riders and those with less cycling experience prior to their e-bike use report that they ride more carefully.

4.5 Experiment

The following hypotheses formed the basis of the experiment:

- Motorists waiting at intersections underestimate the speed of single-track vehicles approaching from the left.
- This error of judgement is more pronounced when the approaching vehicle is an e-bike.
- Estimating speed becomes more difficult when the appearance of the approaching vehicle does not intuitively suggest a fast speed (e.g. elderly e-bike riders).

The experiment was designed as follows: Subjects sitting by the roadside simulated motorists. The subjects had to estimate the speeds of single-track vehicles approaching from the left. Speed, vehicle type, rider age and gender were varied during the experiment.

Results showed that the **speed** of pedal vehicles approaching from the left was **underestimated,** both in **absolute** terms as well as in **comparison with motorcycles.** This method however detected **no difference between bicycles and e-bikes.**

Speed proved to be a significant factor. The underestimation of speeds between 25 and 40 kph was significantly greater than at 15 kph.

The appearance of the single-track vehicle also seems to have an impact on speed assessment.

And finally it was found that speeds are more often **underestimated** from an **elevated and slightly set back position** than from a lower, closer position, which suggests that SUV (sport utility vehicle) drivers are more prone to underestimating the speed of an approaching pedal vehicle.

4.6 Results and conclusion

The accident occurrence has risen in proportion to the number of e-bikes on the road. E-bikes are therefore increasingly becoming an issue for road safety. The question whether the accident risk of e-bikes is higher than that of bicycles cannot be conclusively answered at present. There is a lack of suitable exposure data (performance, duration, number of journeys) available. Serious accidents among e-bike riders are often single-vehicle accidents. This could be due to higher speeds or specific vehicle characteristics (brakes, heavy weight etc.) but also to be influenced by user characteristics (age-related increased vulnerability, psychomotor deficits). Lack of e-bike riding experience or risk awareness can largely be ruled out. Collisions involving e-bikes occur predominantly at intersections and roundabouts when motorists fail to yield right of way to e-bikes approaching from the left. E-bikes are either recognised too late or their speeds underestimated. The latter is generally the case in single-track vehicles and exacerbated at higher speeds. Moreover, motorists allow e-bikes shorter time gaps than bicycles to merge into the traffic flow. This could be due to e-bike riders' slower and seemingly more effortless pedal movements and relaxed posture.

International findings on the risk of injury to cyclists and e-bike riders vary. Swiss police-recorded accident data suggests more severe injury consequences for e-bike riders. According to the current state of knowledge, the cause of the higher accident severity in e-bikes compared with bicycles is mainly due to the age difference observed between the user groups. E-bike riders are older and therefore more vulnerable than bicycle riders. Whether the vehicle (or rather its handling characteristics) plays a part cannot be conclusively determined at present.

In order to help prevent e-bike accidents, the following measures are particularly recommended:

- **In-depth analyses** of e-bike accidents, paying particular attention to serious **single-vehicle accidents**. Research findings on this type of e-bike accident are still scarce. Corresponding new findings should be taken into account when designing concepts for riding courses and campaigns.
- Launching and running a **monitoring programme** providing an on-going analysis of the development of accident occurrence, exposure and other e-bike-relevant parameters. Periodic publication and ease of accessibility must be ensured.
- New e-bike riders without prior experience riding conventional bicycles should be offered **e-bike-specific riding courses;** those with prior cycling experience should be targeted via campaigns.
- Using existing channels to **raise awareness** with regards to the **distinct features** of e-bikes. These include in particular a heightened risk of **single-vehicle accidents,** the consequences of inappropriate speed, vehicle handling, braking behaviour, the slim silhouette, anticipation of potential conflicts, underestimation of speed by motorists as well as riders' own contribution to enhancing their visibility.
- Raising awareness in driver training concerning limited **visibility** as well as **underestimation of speed** in pedal vehicles (with right of way) at intersections, with particular emphasis on **roundabouts**.
- Reviewing the **VSS norms** with regards to the specific requirements of e-bikes.
- Reviewing the existing **road infrastructure**, especially with regards to the applicable minimum visibility distances at intersections (ISSI instrument «Road Safety Inspection»).

- **Further development** of the protective properties of bicycle and **e-bike helmets**. Relevant research and implementation activities should be initiated and supported.
- Encouraging the **development** of higher e-bike safety standards (automatic light activation, adequate braking systems).
- Encouraging the **sale** of **e-bikes with high safety standards** (educating sales personnel, brochures with recommendations, safety labels).