A Review on Test Method Development for Motorcycle Autonomous Emergency Braking Systems

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Abstract:

In the passenger car and truck sector, assistance systems that intervene in emergency situations and thus help to improve vehicle safety have already been successfully used for many years. One common example for this are autonomous emergency braking systems (AEB). These are already standard equipment in many passenger cars or even legally required in trucks in the European Union.

Although motorcyclists are subject to a high risk of suffering severe or fatal injuries in road traffic, systems that actively intervene in emergency situations are not yet available in the motorcycle sector. One reason for this is that passenger car systems cannot easily be adapted due to the motorcycle specific single-track vehicle dynamics. There are characteristic challenges that set limits to the possible application of actively intervening assistance systems. Exceeding these limits when applying a system like AEB on a motorcycle could result in the occurrence of new critical situations that are no longer controllable for the rider.

Still, previous research comes to the conclusion that assistance systems for motorcycles have the potential to increase riding safety and identifies autonomous emergency braking systems for motorcycles (MAEB) as one of the most promising technologies (Savino et al., 2013).

One major challenge in MAEB studies is the conflict of goals between the aim to optimize the effectiveness of MAEB by identifying maximum possible decelerations that can be applied in a safe way and the wish to evaluate ‘natural’ rider reactions to an autonomous braking intervention. For the latter, riders should not anticipate the manoeuvre. They are supposed to be surprised by the autonomous deceleration in order to achieve unbiased results.

Obviously, it is ethically unacceptable to determine feasible deceleration limits with unprepared study participants. Approaching these limits carries the risk of provoking critical situations. During the research described in the paper at hand, a multi-phase approach was developed, in order to overcome the trade-off between achieving maximum effectiveness of braking interventions by identifying maximum feasible decelerations on the one hand and on the other hand evaluating unbiased reactions of unprepared riders.

While other research groups focus on urban riding scenarios at velocities up to 50 km/h in their MAEB research (e.g., Lucci et al., 2021), the investigations described here concentrate on higher velocities as they occur in rural scenarios.

The method starts with a determination of controllability limits during the first phase. In this stage of the investigations, the test persons are expert riders. These experts are experienced professional riding instructors and trainers. They are assumed to be particularly suitable to assessing the skills of unexperienced riders. The experts evaluate different levels of autonomous decelerations concerning their feasibility for unprofessional motorcyclists.

In the second step, the method includes a potential analysis with the aim to compare various intervention strategies (in terms of deceleration profiles) in order to prioritise the most promising approach(es). The potential analysis includes the evaluation of physical
rider reactions that influence the potential velocity reduction as well as an assessment of the acceptance of the autonomous interventions. This investigation is conducted as a participant study with unprofessional riders.

In the third phase, which is again conducted as participant study with unprofessional riders, the method intends to analyse the reactions of riders to unexpected braking interventions in a more detailed way. The focus of this study part is on the relative movements between the riders and the motorcycle. This includes, e.g., upper body and head displacement as well as support forces on the handlebar. A main focus is on the identification of characteristic behaviour and timing. This helps to gain further knowledge about the requirements for the design of autonomous emergency braking interventions that result from characteristic rider behaviour.

The three phases of the investigation method are shown in Figure 1.

![Figure 1. Three phases of the investigation method (Merkel, 2022).](image)

Throughout the research described in this paper, the developed investigation method was exemplarily applied to a prototype MAEB system. The paper provides an overview of the major results of all three phases of MAEB assessment. The method proves to be appropriate and delivers promising results regarding the applicability of autonomous emergency braking systems for motorcycles in the evaluated scenarios. The reproducibility of the measured rider reactions creates confidence that the corresponding effects are predictable, which means that the rider behaviour does not represent a completely incalculable safety-critical factor for the application of MAEB.

The successful application of the method leads to the conclusion that it can serve as a basis for the release of systems that intervene in the longitudinal dynamics. It gives manufacturers and system suppliers the opportunity to systematically prove that their systems are controllable for end users and can be applied without causing additional risks. Thus, the method can contribute to the future use of safety-enhancing assistance systems for motorcycles.

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