MEASURING SAFETY: POSITIVE RISK BALANCE & CONSCIENTIOUS DRIVER

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Introduction

Following the safety argumentation it is required to define top (safety) goals for the selected customer function. For example ISO 21448, “Safety of the intended Function” (SOTIF), states the necessity to proof “*the absence of unreasonable risk due to hazards resulting from functional insufficiencies”*.

In order to satisfy this requirement for a defined system safety measures are required. A possible method to obtain a quantitative safety measure is the POSITIVE RISK BALANCE.

Definition

“Positive risk balance:

Benefit of sufficiently mitigating residual risk of traffic participation due to automated vehicles [...]. This includes the expectation that automated vehicles cause less crashes on average compared to those made by drivers. […]” (ISO/TR 4804:2020[2], analogously derived in ISO/CD 39003)

Equation[3]

$$\frac{}{}\begin{array}{c} Frequency\ of\ the\ occurence\ of\ harm \\ \leq \\ Threshold\ value \end{array}$$

General approach PRB

Step 1: Derive the human driver reference threshold value (statistics, assumptions).

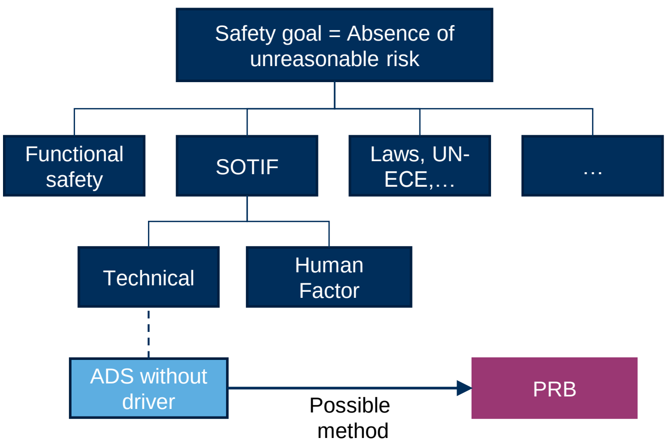
Step 2: Calculate the frequency of occurrence of harm for the ADS (Real world data, Monte-Carlo simulation,…).

Step 3: Compare ADS versus human driver threshold value.

Resulting questions

- How can we obtain the threshold value based on a reference human driver?
- How can we determine the frequency of the occurrence of harm in our development process?

Exemplary sketch of Functional Field of Application



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VERIFICATION
VALIDATION
METHODS

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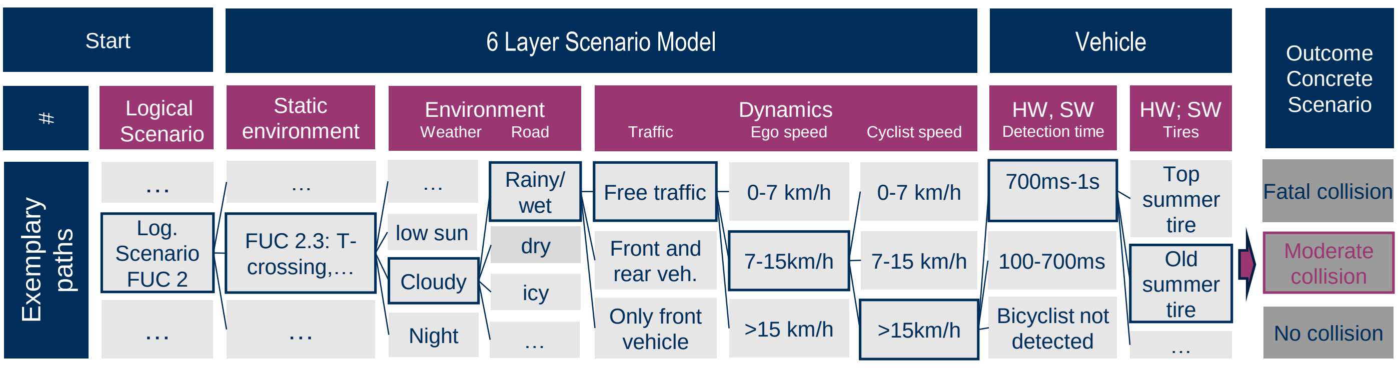

Exemplary scenario decomposition: The collision probability of an ADS is the sum of all possible paths leading to a collision.

Threshold value of reference driver

1. Which accidents should be considered?
- Primarily in operational design domain (ODD)
- Additionally the domain passively affected by the ADS → "functional field of application" (FFoA, see Fig.1)
2. What is the right measure?
- Accident statistics vary over time → consider an average over multiple years.
- Accidents in FFoA per hour or distance to allow for comparison by considering exposure data.
3. Accident statistics
- National accident statistics (Germany: DESTATIS)
- More detailed databases (Germany: GIDAS).
4. Consideration of Safety Margins
- Uncertainties for deriving the safety performance of human drivers should be considered.
- Same for uncertainties in the development process

Frequency of occurence of harm for the ADS

By utilizing a probability tree (see Fig. 3) with appropriate subsection/levels, so called classes of equivalence, the frequency of occurrence of a collision is the sum of all possible paths leading to a collision. Here, we assume for simplicity that harm equals collision. The definition of appropriate classes of equivalence needs to happen in a separate scenario assessment.

Conclusion/Outlook

PRB is a feasible measure to evaluate the fulfillment of the ethical objective: The approval of automated driving systems is only justifiable if it promises at least a mitigation of damage in the sense of a positive risk balance compared to human driving performance. Therefore it is an important element of the safety argumentation of an ADS.

- a possible extension is presented on the next page.

References

[1] Road vehicles - Safety of the intended functionality. Publicly Available Specification ISO/PAS 21448:2019.
[2] Road vehicles — Safety and cybersecurity for automated driving systems — Design, verification and validation. Publicly Available Technical Report ISO/TR 4804:2020.
[3] F. Favarò - Exploring the Relationship Between "Positive Risk Balance" and "Absence of Unreasonable Risk". 2021. Accessed on 2/8/2022, and available at: https://arxiv.org/abs/2110.10566

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Introduction of driver performance

An alternative approach is integrating a driver performance reference in this method. The basic idea is not to directly compare the human performance with the performance of a component such as perception, but to assess the human system performance against the performance of the ADS in terms of (holistic ability to) accident avoidance or mitigation. So, smooth and early vs. hard and late reaction will become comparable.

However, this can also be used for the evaluation of high demands on the system. For example, accident research shows that about 30% of all accidents are caused by drivers whose performance is worse than 90% of all drivers. First, the concept of the conscientious driver will be introduced. We leave the question which percentile has to be used (the 50% or a much higher one) to future research.

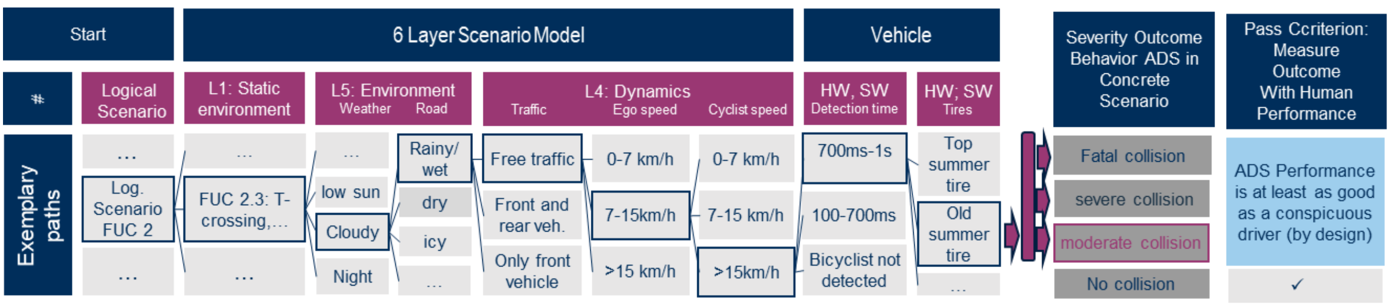
conscientious drivers	drivers who are willing to comply with all traffic regulations, are roadworthy, attentive and do not act grossly negligent.

Controllability of the driving scenario with regard to safety	Performance target for system design		Cumulated performance target
driver equivalent can control the scenario in general (~100 %).	The system must be able to handle the relevant scenario generally. Safe system performance must be demonstrated during development.	State of the art	At least reaching the safety level of current road traffic (in the reference years) of all conscientious driver (driver equivalent) and thus achieving an increase in the level of safety compared to real road traffic.
driver equivalent can control the scenario with restrictions.	System must control the scenario statistically at least comparable to driver equivalent.		
driver equivalent basically cannot control the scenario (~ 0 %).	System does not have to be designed for the scenario but a mitigation measure has to be implemented(at minimum state of the art of technology).		

General

- All scenarios that occur in real road traffic as part of the **ODD** are potentially relevant.
- **The conscientious driver** is willing to comply with all traffic regulations, is fit to drive, attentive and do not act grossly negligent. However, traffic violations cannot be excluded in the event of a momentary lapse or due to external circumstances. The formulated reference are the model drivers as a whole.
- **The assessment of human controllability** is based on the currently available information (if necessary expert judgments).
- **For the assessment of the system performance**, all available findings from the testing and validation of the system are taken into account.
- The comparison with the conscientious drivers must be applied in the context of a given driving scenario to **all essential variants of the driving situation**.
- **The (SOTIF) performance target of the general controllability** is generally equivalent to accident-free driving. Especially because accidents can be caused by negligent conduct of other road users, accident-free driving cannot be guaranteed.

If we add this in the description for the PRB, we get:



Exemplary scenario (in terms of 6-layer model) decomposition: By definition of the conscientious driver this approach leads to a reduction in number and severity of ADS accidents compared to previous numbers.

This concept has already been used in the PEGASUS project in the context of risk assessment and safety argumentation.

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