International Standard

ISO 19725

Road vehicles — Steer-by-wire systems — System safety guidelines

Véhicules routiers — Systèmes de direction électronique — Lignes directrices sur la sécurité du système

First edition
2026-05

Reference number
ISO 19725:2026(en)

COPYRIGHT PROTECTED DOCUMENT

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics, chassis components and driving automation systems testing*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Steer-by-Wire (SbW) systems represent the next generation of technology in vehicle steering. They enable new interior concepts and pave the way for further innovations in vehicle technology. In the context of automated driving, mechanical decoupling between the steering wheel and the steered wheels is becoming increasingly important. To date, there is no experience of widespread use of this technology in the market for large-series passenger cars.

Compared to conventional steering systems, SbW technology results in additional requirements for the safety concept of the vehicle for safe operation.

This document represents a description of a minimal set of safety aspects developed by vehicle manufacturers and system suppliers.

This document considers:

— the description and system boundary of an SbW system,

— basic safety goals,

— general availability requirements,

— requirements for controllability in the event of a first fault, and

— requirements for the operational behaviour after a fault event.

Road vehicles — Steer-by-wire systems — System safety guidelines

1 Scope

This document specifies necessary but not sufficient safety requirements for the use of SbW systems in passenger cars and light commercial vehicles for series application.

This document does not replace the full application of the ISO 26262 series of standards and their implementation in safety-related measures.

This document defines requirements for manual driving where the driver holds the steering wheel.

NOTE Misuse of hands-free driving is not considered.

This document does not contain any requirements for the use of automated lateral vehicle control functions.

The requirements consider systems consisting of a road wheel actuator (RWA), hand wheel actuator (HWA), and a steering wheel for driver input. Deviating concepts need to be analysed by the user for transferability.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15037-1:2019, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

ISO 15037-1, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

ISO 26262-1, *Road vehicles — Functional safety — Part 1: Vocabulary*

ISO 26262-3, *Road vehicles — Functional safety — Part 3: Concept phase*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 26262-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
degradation
degradation stage
DEG
operating conditions of the vehicle within the framework of the *degradation concept* (3.2)

Note 1 to entry: Due to the operating condition of the steering system or supporting systems, a degradation condition can lead to restrictions in the use of the vehicle, e.g. speed limitations. Normal operation N is treated as degradation condition in this document.

3.2
degradation concept
all operating states of the vehicle, including the operating states of the steering system and the supporting vehicle systems after initial and subsequent faults

Note 1 to entry: Operating states include both transition and degradation states after faults, as well as the fault-free normal operation N.

3.3
drive cycle
time span from start to end of a trip

Note 1 to entry: In this document, the term is used in the context of re-transitioning between degradation states.

3.4
expert driver
person who has above-average vehicle dynamics knowledge, skills, ability to assess controllability, capability to conduct the vehicle tests and has regular driving experience

3.5
feedback torque
torque on the steering wheel

Note 1 to entry: An actively generated feedback torque occurs when at least one drive unit of the HWA is active. A passively generated feedback torque occurs when no drive unit of the HWA is active and the driver performs a steering wheel rotation. The feedback torque is used, among other things, to represent the steering feel.

3.6
hand wheel actuator
HWA
component(s) sensing the steering wheel angle and providing a *feedback torque* (3.5)

3.7
immobilization
process in which a stationary vehicle is secured against rolling away

3.8
lane
lateral limited area for the movement of the vehicle, within which the driving task is to be accomplished

3.9
manoeuvre
specified road test

3.10
vehicle lateral manoeuvrability
ability of the vehicle to convert the steering wheel angle request of the driver into a minimal lateral motion reaction while driving below 10 km/h

3.11
manoeuvre sequence
MS
specific group of tests

3.12
normal driver
person who does not have special skills to drive a vehicle

Note 1 to entry: Used to distinguish from expert driver.

3.13
normal operation
N
condition of the steering system and the supporting vehicle systems without safety-critical faults

Note 1 to entry: Minor, non-safety critical deviations within the nominal application range are permissible. The deviation of the behaviour of the steering system and the vehicle relative to the nominal behaviour is within the range expected by the driver.

3.14
passive fallback level
⟨HWA⟩ operating condition at which no active feedback torque is generated

Note 1 to entry: A passive fallback of an HWA can be mechanical base friction or a damping (e.g. electromagnetic, magneto-resistive, back EMF).

3.15
positive diagnostic re-check
diagnostic measure that confirms a previously detected fault is no longer present

3.16
road wheel actuator
RWA
component(s) for actuating the required road wheel angle on the front axle

3.17
steerability
ability of the SbW system to convert the steering wheel angle request of the driver into a design-intended steering movement of the road wheels of the vehicle

3.18
system integrity
characteristics of the SbW system including ASIL capability to meet functional and availability requirements

Note 1 to entry: Functional requirements concern e.g. steering performance, feedback torque and synchronicity. Availability requirements concern e.g. redundancies to maintain steering capability.

Note 2 to entry: Degradation of steering performance or loss of redundancy can reduce the ASIL capability .

3.19
test configuration
combination of the configuration of the test vehicle (see Annex B, B.2.2) and the configurations of the respective vehicle systems (see Annex B, B.2.3) for the tests to demonstrate steerability or vehicle lateral control and controllability in the degradations and transitions

3.20
transition
TR
change between degradation states

Note 1 to entry: A transition represents a time-limited state of a steering system and vehicle. Due to the system state of the steering system or supporting systems, a transition can lead to restrictions in the use of the vehicle, e.g. speed limits.

3.21
vehicle lateral control
ability of the vehicle to convert the steering wheel angle request of the driver into an expected vehicle trajectory according to the available friction coefficient between the tire and the road surface

Note 1 to entry: A trajectory change is also realized by other vehicle systems (e.g. brake, drivetrain, powertrain etc.) beyond the SbW system.

3.22
warning concept
technical measures to warn the driver and the environment in case of faults

3.23
warning symbol
standardized symbol for feedback to the driver of a failure or a degradation state of the SbW system

4 List of symbols

Table 1 — List of used symbols

Size	Symbol	Unit
Vehicle lateral acceleration	a_y	m/s^2
Vehicle longitudinal acceleration	a_x	m/s^2
Distance	a	m
Vehicle width	B	m
Lane width	b	m
Wheelbase	L	m
Pylons distance	d	m
Circle radius	R/R_i	m
Track length	S	m
Vehicle speed	v_x	km/h
Vehicle speed at the beginning of the manoeuvre	$v_{x\,Start}$	km/h
Vehicle speed at the end of the manoeuvre	$v_{x\,End}$	km/h
Disturbance yaw rate	$\Delta\dot{\psi}$	°/s
Disturbance lateral acceleration	Δa_y	m/s^2
Fault duration	t_{Fault}	s

5 Derivation of the safety goals

5.1 System boundary

SbW is a steering system in which the driver's steering intention is detected by a sensor system and transmitted exclusively electrically to the actuator system to apply the road wheel angle. The steering feel is represented to the driver by means of an HWA.

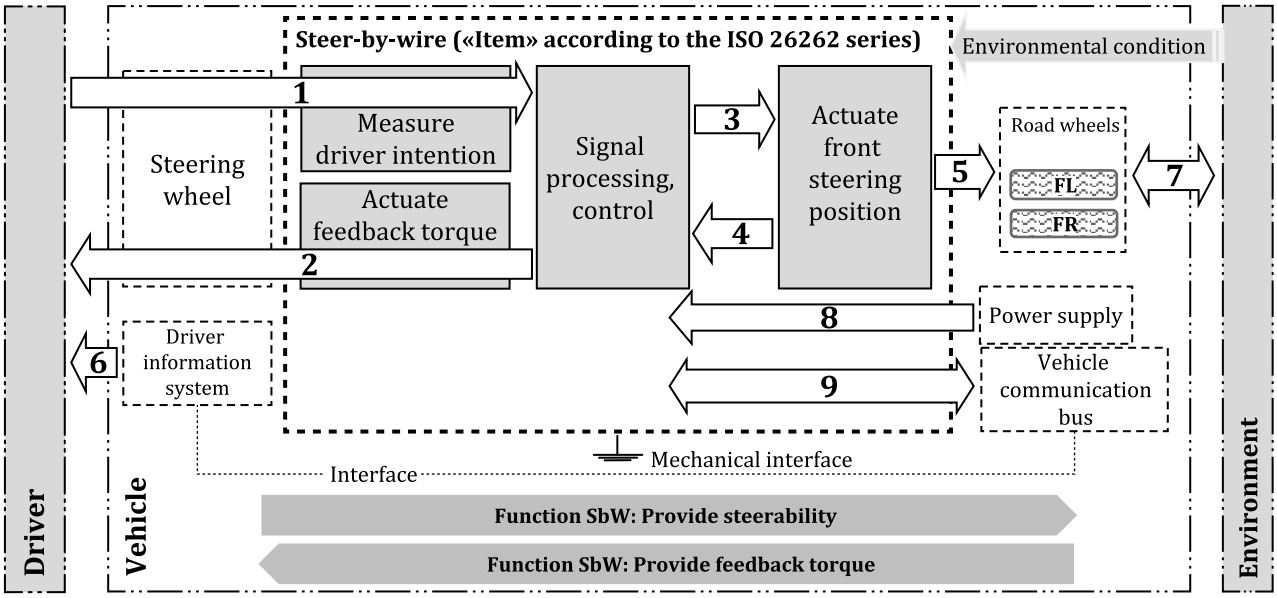
Compared with conventional steering systems (e.g. electromechanical steering, superimposed steering), there is no mechanical connection between the steering wheel and the steered wheels in an SbW system. This conceptual difference results in additional safety requirements and safety-related availability requirements for the steering system in the vehicle.

For an SbW system, steerability or vehicle lateral control shall be maintained during driving despite an electrical fault in the SbW system or in other supporting systems in the vehicle (e.g. vehicle power supply system, vehicle communication).

Figure 1 shows an example of the item SbW according to ISO 26262-1 with the system boundaries of the item, the interfaces to the vehicle as well as functional elements. In addition, the control chains of the two main functions of an SbW system are also shown:

— provide steerability and

— provide feedback torque.



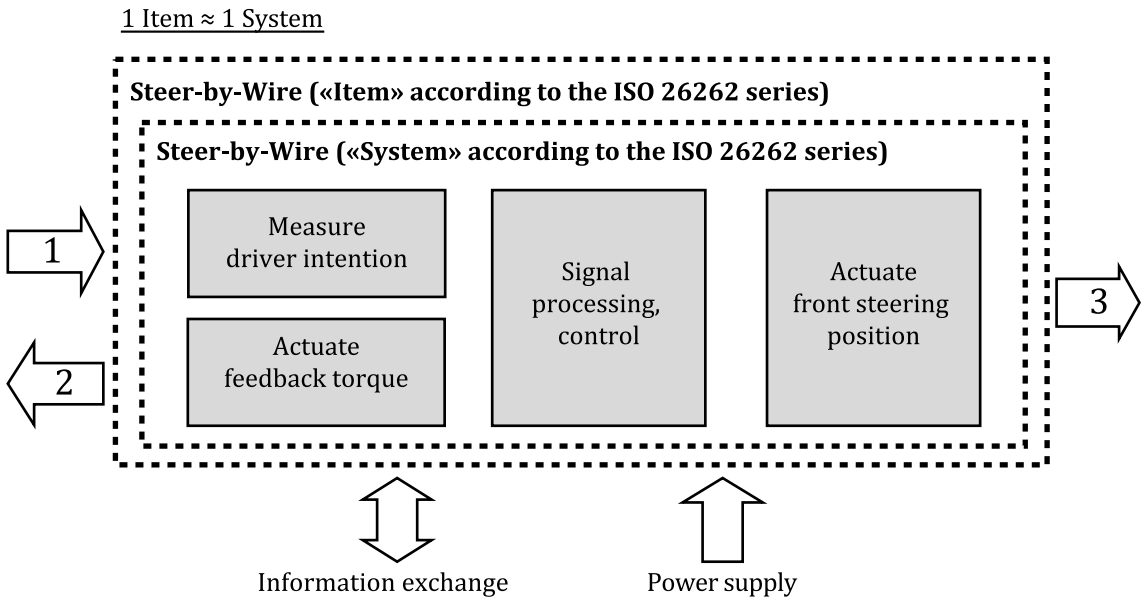
Key

1	measurement of the steering wheel angle
2	actuation of feedback torque via steering wheel (steering feel including haptic warning)
3	target road wheel angle
4	measured variables of actuators
5	road wheel angle (transmission through the mechanical linkage via tie rod and steering linkage to the front wheels)
6	visual or audible information and warnings from the SbW system
7	interaction between wheels and road
8	power supply
9	information exchange

Figure 1 — Definition of item for SbW

An SbW system with the specified functions is defined as one item according to the definition in ISO 26262-1 and ISO 26262-5 [1].

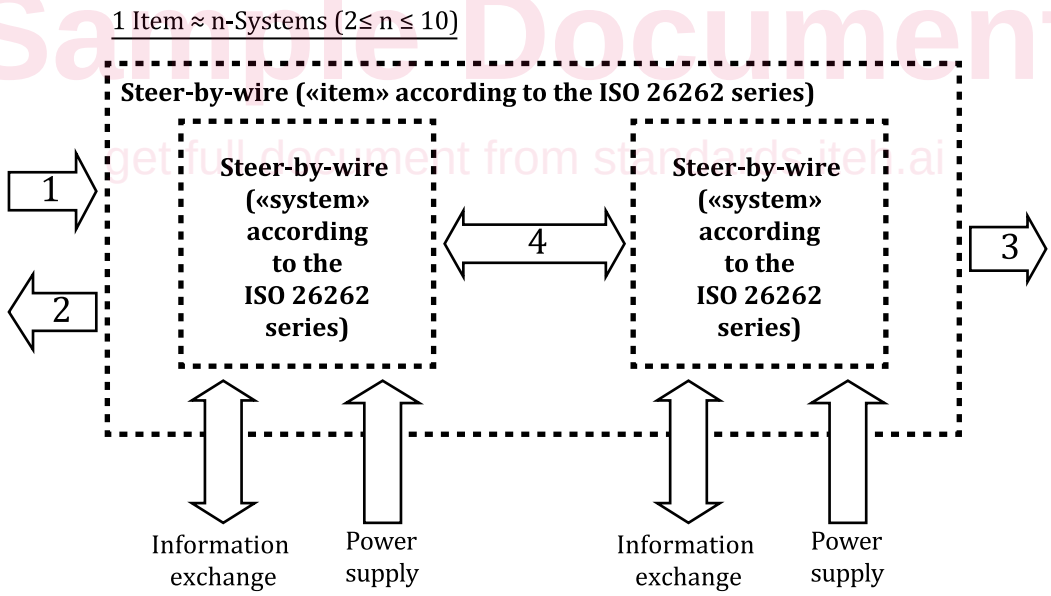
The item SbW can either be defined as one system or as a combination of several systems according to ISO 26262-1 and ISO 26262-5 [1], see Figure 2 and Figure 3.



Key

1 steering wheel input
2 feedback torque (steering feel including haptic warning)
3 road wheel angle

Figure 2 — Option 1: Definition of system(s) for SbW according to the ISO 26262 series [2]



Key

1 steering wheel input
2 feedback torque (steering feel including haptic warning)
3 road wheel angle
4 information exchange between systems

NOTE The definition "1 item = *n* systems (2 ≤ *n* ≤ 10)" follows the requirements of the ISO 26262 series[2].

Figure 3 — Option 2: Definition of system(s) for SbW according to the ISO 26262 series [2]

An example of breakdown in physical system architecture(s) for both variants and for the share of development responsibilities between OEM and supplier is given in Annex C.

5.2 SbW malfunctioning behaviours

Based on the functions of the SbW system listed in 5.1:

— provide steerability, and

— provide feedback torque,

the following SbW malfunctioning behaviours are considered:

— self-steering;

— loss of steerability;

— loss of feedback torque;

— blocking of the steering system;

— loss of synchronization between steering wheel angle and road wheel angle.

The malfunctioning behaviours are defined from driver's perspective, that means they represent a faulty behaviour as it can be experienced by the driver:

— "self-steering" can occur if the road wheels are unintentionally moved

  — due to a fault in the function "Provide steerability" (e.g. faults in the measurement, signal processing, actuation), or

  — due to a fault in the function "Provide feedback torque" (e.g. faults in the measurement, signal processing, actuation) leading to an unintended movement of the steering wheel,

— "loss of steerability" can occur if the driver's intention is not actuated at the road wheels;

— "loss of feedback torque" can occur if no or insufficient torque is applied to the steering wheel;

— "blocking of the steering system" can occur if the forces to rotate the steering wheel are too high for the driver;

— "loss of synchronization between steering wheel angle and road wheel angle" can occur if the road wheel angle and steering wheel angle are misaligned, e.g. due to

  — delayed road wheel angle actuation,

  — misalignment at vehicle wake-up.

In addition to the above listed malfunctions, a complete analysis of all E/E malfunctions in accordance with ISO 26262-3 as well as mechanical failures shall be conducted for a specific SbW system.

5.3 Safety goals

5.3.1 General

The following safety goals and their criticality ratings are derived from the SbW malfunctioning behaviours listed in 5.2:

— SG1: Self-steering shall be prevented while driving.

— SG2: Loss of steerability shall be prevented while driving.

— SG3: Loss of feedback torque to the driver shall be prevented while driving.

— SG4: Unintentional blocking of the steering wheel shall be prevented while driving.

— SG5: Unintended loss of synchronization between the SbW actuators shall be prevented while driving.

Table 2 shows the allocation of the SbW malfunctioning behaviours to the safety goals.

Table 2 — Allocation of SbW malfunctions to safety goals

Function of SbW system	SbW malfunction	Safety goals
Provide steerability	Self-steering (RWA)	SG1
	Loss of steerability Blocking of the steering system (RWA)	SG2
	Loss of synchronization between steering wheel angle and road wheel angle	SG5
Provide feedback torque	Self-Steering (HWA)	SG1
	Loss of feedback torque	SG3
	Blocking of the steering system (HWA)	SG4

NOTE 1 In the context of the safety goals, "while driving" means that the vehicle is in a state where the driver has lateral and longitudinal control of the vehicle. The criticality (ASIL rating) of a safety goal violation is speed dependent. At very low speeds (e.g. 10 km/h with a corresponding warning concept), the risk is much lower than at higher speeds due to the significantly reduced kinetic energy.

NOTE 2 This document evaluates the criticality of the safety goals for E/E faults with Automotive Safety Integrity Level (ASIL) according to ISO 26262 series [2].

NOTE 3 The SbW malfunction “blocking of the steering system” as per 5.2 can be caused by blocking of the HWA (SG4) or blocking of the RWA (SG2).

The listed safety goals are not derived from a complete hazard analysis and risk assessment according to ISO 26262 series [2] but are based on the generic failure modes. Therefore, the listed safety goals represent only a minimum set of safety goals.

This document does not relieve the user from performing a complete HARA according to ISO 26262-3 for a specific SbW system.

5.3.2 Safety goal SG1: Self-steering shall be prevented while driving

5.3.2.1 Explanation

Self-steering is an unintended steering angle change (RWA and/or HWA) caused by a unintended force of the RWA or an unintended torque of the HWA. The safety goal is classified as ASIL D.

EXAMPLE Possible causes for an unintended RWA force or an unintended feedback torque including failures in the entire control path: sensors, communication, control and actuators. The type of unintended actuator control can follow different failure patterns, e.g. wrong amplitude, overshoot, wrong direction, superimposed, oscillating.

5.3.2.2 Acceptance criteria

Faults in an SbW system which can lead to the violation of the safety goal shall be mitigated in a suitable manner. It has to be ensured that the vehicle can be kept in the lane (see Clause 7).

5.3.2.3 Safe state vehicle

The safe state on vehicle level for the function "provide steerability" is reached when the vehicle speed is reduced to ≤ 10 km/h with a corresponding warning.

The safe state on vehicle level for the function "Provide feedback torque" is reached when general controllability (C0 controllability) is given or when the vehicle speed is reduced to ≤ 10 km/h with appropriate warning.

NOTE UN Regulation No. 79 [3] refers to the threshold of ≤ 10 km/h in the event of a fault. Depending on driving situations, furthermore the degradation concept defines the transition of the vehicle into vehicle standstill within the vehicle safe state.

When transitioning the vehicle to the safe state, the requirements of the degradation concept shall be met (see Clause 8).

The safe state at vehicle level can only be reached and ensured by considering systems outside the SbW system or considering the driver.

5.3.2.4 Safe state SbW system

The safe state on SbW system level for the function "Provide steerability" is to continue the operation of the function until the safe state is reached at the vehicle level. Faulty components shall be isolated or deactivated. Remaining required redundancies are to be activated or maintained.

The safe state on SbW system level for the function "Provide feedback torque" is to continue the operation of the function until the safe state at the vehicle level is reached or internal SbW mechanism exists where the functionality of the active feedback torque is no longer required for safety reasons. Faulty components shall be isolated or deactivated. Remaining required redundancies shall be activated or kept active or alternative mitigation measures shall be applied.

EXAMPLE Example mitigation measures can be increased mechanical friction or damping.

In order to prevent violation of other safety goals, following additional measures shall be considered:

— remaining redundant control and power supply channels shall be activated or kept active;

— minimum steering performance according to the degradation concept shall be ensured.

5.3.3 Safety goal SG2: Loss of steerability shall be prevented while driving

5.3.3.1 Explanation

Loss of the steerability is a failure in the SbW system that leads to the loss of the function “Provide steerability” and cannot be sufficiently compensated by other systems for vehicle lateral control. The safety goal is classified as ASIL D.

EXAMPLE Possible failure causes for a failure of the steerability include the entire control path: sensors, communication, control, actuators, power supply, as well as mechanical components.

5.3.3.2 Acceptance criteria

In the event of faults in an SbW system which can lead to the violation of the safety goal shall be mitigated in a suitable manner. It shall be ensured that the vehicle can be kept in the lane (see Clause 7). The minimum steering performance shall be ensured in accordance with the degradation concept (see Clause 8).

5.3.3.3 Safe state vehicle

The safe state on vehicle level is reached when the vehicle speed is reduced to ≤ 10km/h with appropriate warning.

NOTE 1 UN Regulation No. 79 [3] refers to the threshold of ≤ 10 km/h in the event of a fault. Depending on driving situations, furthermore the degradation concept defines the transition of the vehicle into vehicle standstill within the vehicle safe state. The safe state with corresponding driver warning is a sufficient risk mitigation according to ISO 26262 series [2]. The residual risk of a loss of steerability at vehicle speeds ≤ 10km/h with corresponding driver warning does not lead to an ASIL classification.