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Motorcycles — Functional safety

Motocycles — Sécurité fonctionnelle

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Foreword

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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 documents 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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 38, *Motorcycles and mopeds*.

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Introduction

This Publicly Available Standard is the adaptation of ISO 26262:2011 (all parts) to comply with needs specific to the application sector of electrical and/or electronic (E/E) systems installed in motorcycles, and provides the partial tailoring activities of ISO 26262-2:2011, Clause 6, ISO 26262-3:2011, Clause 7, and ISO 26262-4:2011, Clauses 8 and 9.

ISO 26262:2011 (all parts) is intended to be applied to safety-related systems that include one or more E/E systems and that are installed in series production passenger cars with a maximum gross vehicle mass up to 3 500 kg. ISO 26262:2011 (all parts) does not address unique E/E systems in special purpose vehicles such as vehicles designed for drivers with disabilities.

The motorcycle industry recognizes the need to use appropriate safety-related techniques to avoid unreasonable risk resulting from random or systematic faults of E/E systems.

Many of the requirements specified in ISO 26262:2011 (all parts) are applicable for E/E systems produced for the motorcycle industry and therefore it was accepted by SC 22 (superseded to SC 38) that the E/E systems developed for motorcycles should be within the scope of ISO 26262:2011 (all parts).

However, the adoption of ISO 26262:2011 (all parts) can lead to an inappropriate estimation of motorcycle risk. Therefore, some existing ISO 26262:2011 (all parts) requirements are considered infeasible for the motorcycle industry, e.g. user test under real-life conditions.

Motorcycle Safety Integrity Level (MSIL) is the output of hazard analysis and risk assessment. This is then apportioned between the risk reduction mechanisms and measures assigned to E/E systems using Automotive Safety Integrity Level (ASIL) and the risk reduction taken care of by external measures and/or other technologies [which are outside the scope of ISO 26262:2011 (all parts) and this Publicly Available Standard].

Specifically in the motorcycle industry, a greater proportion of the overall risk reduction is generally apportioned to external measures (for example, riding rules, training/qualification of riders, personal protective equipment, e.g. helmets and infrastructure features).

The worldwide established level of technology ("state-of-the-art") in the motorcycle industry suggests that ASIL requirements are not appropriate for motorcycles. This is addressed through the alignment between MSIL and ASIL.

It is acknowledged that product development processes and technical solutions within the motorcycle industry are inhomogeneous with those of the automobile industry; therefore, the difference between MSIL and ASIL has been made to accommodate worldwide capability.

It can be necessary to modify certain requirements, methods, and measures of ISO 26262:2011 (all parts) in order to adapt the standards' best practices to match state-of-the-art practices for motorcycle functional safety.

Other areas of ISO 26262:2011 (all parts) which would be affected by inclusion of motorcycles within the scope of the standard have also been identified and necessary changes recommended. The content of this Publicly Available Standard requires consideration and acceptance by SC 32 in order to facilitate the inclusion of motorcycles within the scope of ISO 26262:2011 (all parts) Edition 2.

Figure 1 shows the structure and relation of this Publicly Available Standard and ISO 26262:2011 (all parts).

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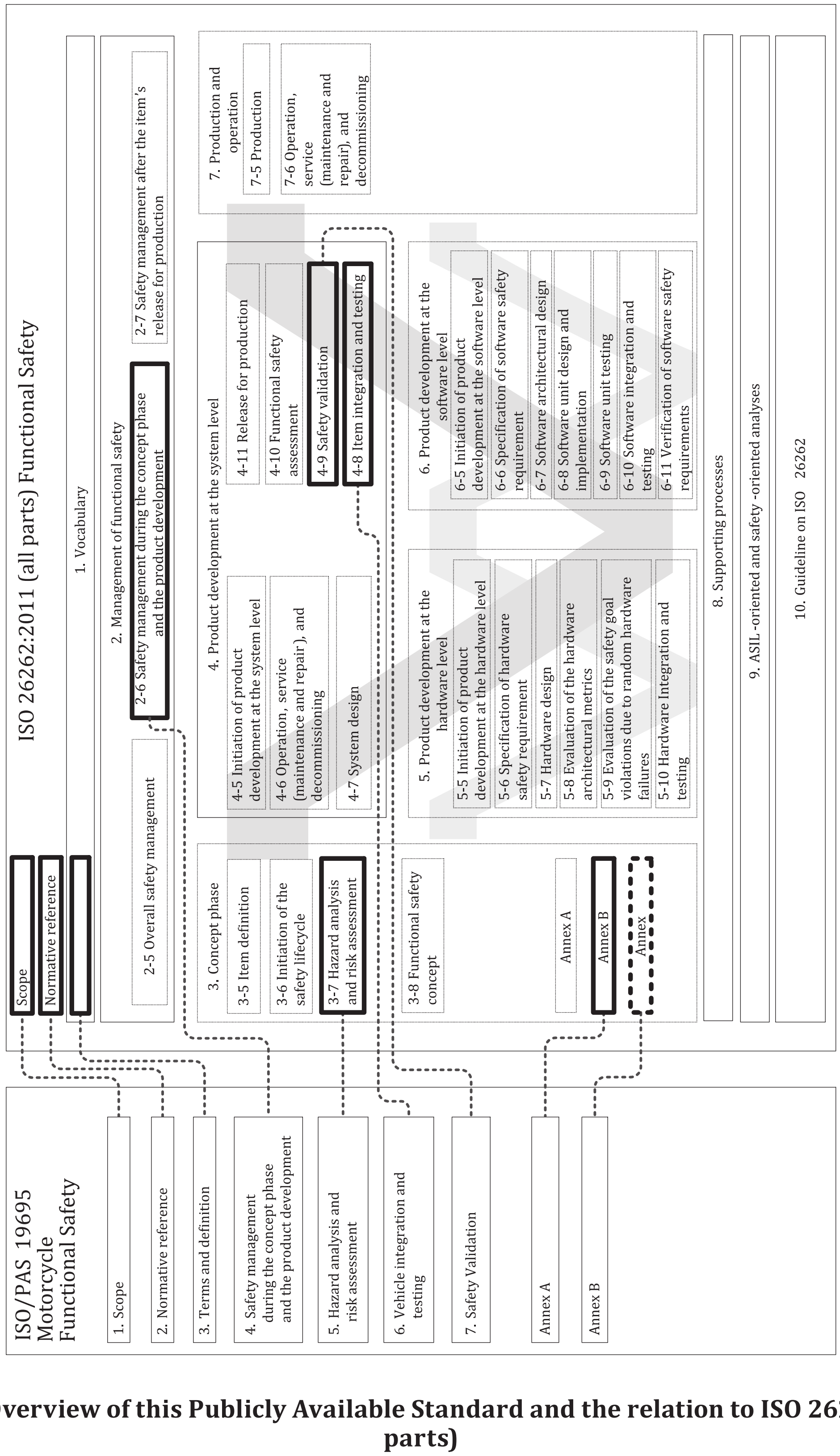

Figure 1 — Overview of this Publicly Available Standard and the relation to ISO 26262:2011 (all parts)

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Motorcycles — Functional safety

1 Scope

This Publicly Available Standard is intended to be applied to safety-related systems that include one or more electrical and/or electronic (E/E) systems and that are installed in series production two-wheeled or three-wheeled motorcycles.

This Publicly Available Standard does not address unique E/E systems in special purpose vehicles, such as vehicles designed for competition.

This Publicly Available Standard addresses possible hazards caused by malfunctioning behaviour of E/E safety-related systems, including interaction of these systems. It does not address hazards related to electric shock, fire, smoke, heat, radiation, toxicity, flammability, reactivity, corrosion, release of energy, and similar hazards, unless directly caused by malfunctioning behaviour of E/E safety-related systems.

This Publicly Available Standard does not address the nominal performance of E/E systems, even if dedicated functional performance standards exist for these systems.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 26262-1:2011, *Road vehicles — Functional safety — Part 1: Vocabulary*

ISO 26262-2:2011, *Road vehicles — Functional safety — Part 2: Management of functional safety*

ISO 26262-3:2011, *Road vehicles — Functional safety — Part 3: Concept phase*

ISO 26262-4:2011, *Road vehicles — Functional safety — Part 4: Product development at the system level*

ISO 26262-5:2011, *Road vehicles — Functional safety — Part 5: Product development at the hardware level*

ISO 26262-6:2011, *Road vehicles — Functional safety — Part 6: Product development at the software level*

ISO 26262-8:2011, *Road vehicles — Functional safety — Part 8: Supporting processes*

ISO 26262-9:2011, *Road vehicles — Functional safety — Part 9: Automotive Safety Integrity Level (ASIL)-oriented and safety-oriented analyses*

3 Terms, definitions, and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 26262-1:2011 and the following apply

3.1
expert rider
role filled by persons capable of evaluating controllability classifications based on operation of actual motorcycles

Note 1 to entry: An expert rider is a rider who has the

— skill to evaluate controllability,

— capability to conduct the vehicle test, and

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— knowledge to evaluate motorcycle controllability characteristics with respect to a representative rider's riding capability.

Note 2 to entry: See Annex B for information relating to the use of expert riders.

3.2
motorcycle safety integrity level
MSIL
one of four levels that specify the item's or element's necessary ISO 26262:2011 (all parts) risk reduction requirements and safety measures to apply for avoiding unreasonable residual risk for items and elements used specifically in motorcycle applications, with D representing the most stringent and A the least stringent level

4 Safety management during the concept phase and the product development

4.1 Objective

The objective of this Clause is to define the independency requirements of confirmation measures associated with ASIL, converted from MSIL.

4.2 General

Safety management includes the responsibility to ensure that the confirmation measures are performed. Depending on the applicable ASIL, some confirmation measures require independence regarding resources, management, and release authority (see 4.4).

Confirmation measures include confirmation reviews, functional safety audits, and functional safety assessments.

— The confirmation reviews are intended to check the compliance of selected work products to the corresponding requirements of ISO 26262 (all parts).

— A functional safety audit evaluates the implementation of the processes required for the functional safety activities.

— A functional safety assessment evaluates the functional safety achieved by the item.

In addition to the confirmation measures, verification reviews are performed. These reviews, which are required in other parts of ISO 26262, are intended to verify that the associated work products fulfil the project requirements, and the technical requirements with respect to use cases and failure modes.

Table 1 lists the required confirmation measures. ISO 26262-2:2011, Annex D lists the reviews concerning verification and refers to the applicable parts of ISO 26262.

4.3 Input to this Clause

4.3.1 Prerequisites

See applicable prerequisites of the relevant phases of the safety lifecycle in which confirmation measures are planned or carried out.

4.3.2 Further supporting information

See applicable further supporting information of the relevant phases of the safety lifecycle in which confirmation measure is planned or carried out.

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4.4 Requirements and recommendations

4.4.1 General

The organizations involved in the execution of the safety lifecycle shall comply with 4.4.2 for items that have at least one safety goal with an ASIL A, B, or C, unless stated otherwise.

4.4.2 Confirmation measures: Types, independency, and authority

4.4.2.1 The confirmation measures specified in Table 1 shall be performed, in accordance with the required level of independency as specified in ISO 26262-2:2011, Table 2, 6.4.3.5 i), 6.4.8, and 6.4.9.

NOTE 1 The confirmation reviews are performed for those work products that are specified in Table 1 and required by the safety plan.

NOTE 2 A confirmation review includes the checking of correctness with respect to formality, contents, adequacy, and completeness regarding the requirements of ISO 26262:2011 (all parts).

NOTE 3 Table 1 includes the confirmation measures. An overview of the verification reviews is given in ISO 26262-2:2011, Annex D.

NOTE 4 A report that is a result of a confirmation measure includes the name and revision number of the work products or process documents analysed (see ISO 26262-8:2011, 10.4.5).

NOTE 5 If the item changes subsequent to the completion of confirmation reviews or functional safety assessments, then these will be repeated or supplemented (see ISO 26262-8:2011, 8.4.5.2).

NOTE 6 The aim of each confirmation measure is given in ISO 26262-2:2011, Annex C.

NOTE 7 Confirmation measures such as confirmation reviews and functional safety audits can be merged and combined with the functional safety assessment to support the handling of comparable variants of an item.

Table 1 — Required confirmation measures, including the required level of independency

Confirmation measures	Degree of independency[a] applies to ASIL, converted from MSIL			Scope
	A	B	C	
Confirmation review of the hazard analysis and risk assessment of the item (see Clause 5, ISO 26262-3:2011, Clauses 5, and if applicable, ISO 26262-8:2011, Clause 5) Independence with regard to those generating the work product	I2	I2	I2	The scope of this review shall include the correctness of the determined ASILs and quality management (QM) ratings of the identified hazardous events for the item, and a review of the safety goals

a The notations are defined as follows:

— —: no requirement and no recommendation for or against regarding this confirmation measure;

— I0: the confirmation measure should be performed; however, if the confirmation measure is performed, it shall be performed by a different person;

— I1: the confirmation measure shall be performed, by a different person;

— I2: the confirmation measure shall be performed, by a person from a different team, i.e. not reporting to the same direct superior.

b A software tool development is outside the item's safety lifecycle whereas the qualification of such a tool is an activity of the safety lifecycle.

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Table 1 *(continued)*

Confirmation measures	Degree of independency[a] applies to ASIL, converted from MSIL			Scope
	A	B	C	
Confirmation review of the safety plan (see ISO 26262-2:2011, 6.5.1) Independence with regard to those generating the work product	—	I1	I2	Applies to the highest ASIL among the safety goals of the item
Confirmation review of the item integration and testing plan (see ISO 26262-4:2011) Independence with regard to those generating the work product	I0	I1	I2	Applies to the highest ASIL among the safety goals of the item
Confirmation review of the validation plan (see ISO 26262-4:2011) Independence with regard to those generating the work product	I0	I1	I2	Applies to the highest ASIL among the safety goals of the item
Confirmation review of the safety analyses (see ISO 26262-9:2011, Clause 8) Independence with regard to those generating the work product	I1	I1	I2	Applies to the highest ASIL among the safety goals of the item
Confirmation review of the software tool qualification report[b] (see ISO 26262-8:2011, Clause 11) Independence with regard to the persons performing the qualification of the software tool	—	I0	I1	Applies to the highest ASIL of the requirements that can be violated by the use of the tool
Confirmation review of the proven in use arguments (analysis, data, and credit) of the candidates (see ISO 26262-8:2011, Clause 14) Independence with regard to those developing the argument	I0	I1	I2	Applies to the ASIL of the safety goal or requirement related to the considered behaviour, or function, of the candidate
Confirmation review of the completeness of the safety case (see ISO 26262-2:2011, 6.5.3) Independence with regard to those developing the safety case	I0	I1	I2	Applies to the highest ASIL among the safety goals of the item
Functional safety audit in accordance with ISO 26262-2:2011, 6.4.8 Independence with regard to the developers of the item and project management	—	I0	I2	Applies to the highest ASIL among the safety goals of the item

[a] The notations are defined as follows:

— —: no requirement and no recommendation for or against regarding this confirmation measure;

— I0: the confirmation measure should be performed; however, if the confirmation measure is performed, it shall be performed by a different person;

— I1: the confirmation measure shall be performed, by a different person;

— I2: the confirmation measure shall be performed, by a person from a different team, i.e. not reporting to the same direct superior.

[b] A software tool development is outside the item's safety lifecycle whereas the qualification of such a tool is an activity of the safety lifecycle.

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Table 1 *(continued)*

Confirmation measures	Degree of independency[a] applies to ASIL, converted from MSIL			Scope
	A	B	C	
Functional safety assessment in accordance with ISO 26262-2:2011, 6.4.9 Independence with regard to the developers of the item and project management	—	I0	I2	Applies to the highest ASIL among the safety goals of the item

[a] The notations are defined as follows:

— —: no requirement and no recommendation for or against regarding this confirmation measure;

— I0: the confirmation measure should be performed; however, if the confirmation measure is performed, it shall be performed by a different person;

— I1: the confirmation measure shall be performed, by a different person;

— I2: the confirmation measure shall be performed, by a person from a different team, i.e. not reporting to the same direct superior.

[b] A software tool development is outside the item's safety lifecycle whereas the qualification of such a tool is an activity of the safety lifecycle.

4.4.2.2 The persons who carry out a confirmation measure shall have access to, and shall be supported by, the persons and organizational entities that carry out safety activities during the item development.

4.4.2.3 The persons who carry out a confirmation measure shall have access to the relevant information and tools.

4.5 Work products

Confirmation measure reports, resulting from 4.4.2 and ISO 26262-2:2011, Table 2, 6.4.8 and 6.4.9

5 Hazard analysis and risk assessment

5.1 Objective

This Clause provides a tailoring of ISO 26262-3:2011, Clause 7 for motorcycles.

The objective of the hazard analysis and risk assessment for motorcycles is to identify and to categorize the hazards that malfunctions in the item can trigger and to formulate the safety goals related to the prevention or mitigation of the hazardous events, in order to avoid unreasonable risk.

The objective of this Clause is to specify the necessary requirements that need to be complied with in order to perform a motorcycle specific hazard analysis and risk assessment.

5.2 General

Due to the fact that the dynamic behaviour of motorcycles differs greatly from that of passenger cars, and that controllability of motorcycle specific hazardous events could place more emphasis on the rider, it is recognized that the method of performing risk assessment requires a degree of tailoring to best suit motorcycle specific hazardous events.

Hazard analysis, risk assessment, and MSIL determination are used to determine the safety goals for the item such that an unreasonable risk is avoided. For this, the item is evaluated with regard to its potential hazardous events. Safety goals and their assigned MSIL are determined by a systematic evaluation of hazardous events. The MSIL is determined by considering the estimate of the impact

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factors, i.e. severity, probability of exposure, and controllability. It is based on the item's functional behaviour; therefore, the detailed design of the item does not necessarily need to be known.

5.3 Input to this Clause

5.3.1 Prerequisites

The following information shall be available:

— item definition in accordance with ISO 26262-3:2011, 5.5.

5.3.2 Further supporting information

The following information can be considered:

— impact analysis, if applicable (see ISO 26262-3:2011, 6.5.1);

— relevant information on other independent items (from external source).

5.4 Requirements and recommendations

5.4.1 Initiation of the hazard analysis and risk assessment

5.4.1.1 The hazard analysis and risk assessment shall be based on the item definition.

5.4.1.2 The item without internal safety mechanisms shall be evaluated during the hazard analysis and risk assessment, i.e. safety mechanisms intended to be implemented or that have already been implemented in predecessor items shall not be considered in the hazard analysis and risk assessment.

NOTE 1 In the evaluation of an item, available and sufficiently independent external measures can be beneficial.

NOTE 2 Safety mechanisms of the item that are intended to be implemented or that have already been implemented are incorporated as part of the functional safety concept.

5.4.2 Situation analysis and hazard identification

5.4.2.1 Situation analysis

5.4.2.1.1 The operational situations and operating modes in which an item's malfunctioning behaviour will result in a hazardous event shall be described, both for cases when the vehicle is correctly used and when it is incorrectly used in a foreseeable way.

NOTE The operational situation addresses the limits within which the item is expected to behave in a safe manner.

EXAMPLE 1 A normal motorcycle is not expected to travel on unimproved or unpaved surfaces at high speed.

EXAMPLE 2 A normal motorcycle is not expected to be used for road race, motocross, or trial events.

5.4.2.2 Hazard identification

5.4.2.2.1 The hazards shall be determined systematically by using adequate techniques.

NOTE Techniques such as brainstorming, checklists, review of quality history, analysis of accident data, FMEA, and field studies can be used for the extraction of hazards at the item level.

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5.4.2.2.2 Hazards shall be defined in terms of the conditions or behaviour that can be observed at the vehicle level.

NOTE 1 In general, each hazard will have a variety of potential causes related to the item's implementation but they do not need to be considered in the hazard analysis and risk assessment for the definition of the conditions or behaviour, which result from a functional behavior of the item.

NOTE 2 Only hazards associated with the item itself can be considered, every other system (external measure) is presumed to be functioning correctly provided it is sufficiently independent.

5.4.2.2.3 The hazardous events shall be determined for relevant combinations of operational situations and hazards.

5.4.2.2.4 It shall be ensured that the chosen level of detail of the list of operational situations does not lead to an inappropriate lowering of the MSIL.

NOTE A very detailed list of operational situations (see 5.4.2.1) for one hazard, with regard to the vehicle state, road conditions, and environmental conditions, can lead to a very granular classification of hazardous events. This can make it easier to rate controllability and severity. However, a larger number of different operational situations can lead to a consequential reduction of the respective classes of exposure, and thus to an inappropriate lowering of the MSIL.

5.4.2.2.5 The consequences of hazardous events shall be identified.

NOTE If failures at an item level induce the loss of several functions of the item, then the situation analysis and hazard identification considers the resulting hazardous events from the combined malfunctional behaviour of the item or vehicle.

EXAMPLE Failure of the vehicle electrical power supply system can cause the simultaneous loss of a number of functions including "engine torque" and "forward illumination".

5.4.2.2.6 If there are hazards identified in 5.4.2.2 that are outside of the scope of this Publicly Available Standard (see Clause 1), then the need for appropriate measures to mitigate or control these hazards shall be highlighted and reported to the responsible persons.

NOTE As these hazards are outside the scope of this Publicly Available Standard, hazard classification is not necessary.

5.4.3 Classification of hazardous events

5.4.3.1 All hazardous events identified in 5.4.2.2.3 shall be classified, except those that are outside the scope of this Publicly Available Standard.

NOTE If classification of a given hazard with respect to severity, probability of exposure, or controllability is difficult to make, it is classified conservatively, i.e. whenever there is reasonable doubt, a higher S, E, or C classification is given rather than a lower.

5.4.3.2 The severity of potential harm shall be estimated based on a defined rationale for each hazardous event. The severity shall be assigned to one of the severity classes S0, S1, S2, or S3 in accordance with Table 2.

NOTE 1 The risk assessment of hazardous events focuses on the harm to each person potentially at risk, including the rider or the passengers of the vehicle causing the hazardous event, and other persons potentially at risk such as cyclists, pedestrians, or occupants of other vehicles. The description of the Abbreviated Injury Scale (AIS) can be used for characterising the severity and can be found in Annex A. For informative examples of different types of severity and accidents, see Annex A. Where available, motorcycle appropriate accident databases can be used to provide a basis for determining severity levels.

NOTE 2 The severity class can be based on a combination of injuries and this can lead to a higher evaluation of the severity than would result from just looking at single injuries.

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NOTE 3 The estimate considers reasonable sequences of events for the situation being evaluated.

NOTE 4 The severity determination is based on a representative sample of individuals for the target markets.

NOTE 5 Standard protective equipment (e.g. helmet, protective jacket, gloves, and boots) as prescribed in the vehicle user manual is assumed to be in use.

Table 2 — Classes of severity

	Class			
	S0	**S1**	**S2**	**S3**
Description	No injuries	Light and moderate injuries	Severe and life-threatening injuries (survival probable)	Life-threatening injuries (survival uncertain), fatal injuries

5.4.3.3 The severity class S0 may be assigned if the hazard analysis determines that the consequences of a malfunctioning behaviour of the item are clearly limited to material damage and do not involve harm to persons. If a hazard is assigned to severity class S0, no MSIL assignment is required.

5.4.3.4 The probability of exposure of each operational situation shall be estimated based on a defined rationale for each hazardous event. The probability of exposure shall be assigned to one of the probability classes, E0, E1, E2, E3, and E4, in accordance with Table 3.

NOTE 1 For classes E1 to E4, the difference in probability from one E class to the next is an order of magnitude.

NOTE 2 The exposure determination is based on a representative sample of operational situations for the target markets.

NOTE 3 For details and examples related to the probability of exposure, see Annex A.

Table 3 — Classes of probability of exposure regarding operational situations

	Class				
	E0	**E1**	**E2**	**E3**	**E4**
Description	Extremely low probability	Very low probability	Low probability	Medium probability	High probability

5.4.3.5 The number of vehicles equipped with the item shall not be considered when estimating the probability of exposure.

NOTE The evaluation of the probability of exposure is performed assuming each vehicle is equipped with the item. This means that the argument “the probability of exposure can be reduced, because the item is not present in every vehicle (as only some vehicles are equipped with the item)” is not valid.

5.4.3.6 Class E0 may be used for those situations that are suggested during hazard analysis and risk assessment, but which are considered to be extremely unusual and therefore not followed up. A rationale shall be recorded for the exclusion of these situations. If a hazard is assigned to exposure class E0, no MSIL assignment is required.

EXAMPLE E0 can be used in the case of “force majeure” risk (see A.3).

5.4.3.7 The controllability of each hazardous event, by the person(s) potentially at risk, shall be estimated based on a defined rationale for each hazardous event. The controllability shall be assigned to one of the controllability classes C0, C1, C2, and C3, in accordance with Table 4.

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NOTE 1 The evaluation of the controllability is an estimate of the probability that the person(s) potentially at risk are able to gain sufficient control of the hazardous event, such that they are able to avoid the specific harm. For this purpose, the parameter C is used, with the classes C0, C1, C2, and C3, to classify the potential of avoiding harm. Some examples, which serve as an interpretation of these classes, are listed in Table A.4. Estimates can be made using either experimental or analytical procedures.

NOTE 2 For motorcycles, it is assumed that the rider is in an appropriate condition to ride (e.g. he/she is not tired), has the appropriate riding training (he/she has a rider's licence), understands the operational characteristics of the motorcycle in use, and is complying with all applicable legal regulations, including due care requirements to avoid risks to other traffic participants.

NOTE 3 Where the hazardous event is not related to the control of the vehicle direction and speed, e.g. potential limb entrapment in moving parts, the controllability can be an estimate of the probability that the person at risk is able to remove themselves, or to be removed by others from the hazardous situation. When considering controllability, note that the person at risk might not be familiar with the operation of the item.

NOTE 4 When controllability involves the actions of multiple traffic participants, the controllability assessment can be based on the controllability of the vehicle with the malfunctioning item, and the likely action of other participants.

NOTE 5 For motorcycle hazardous events, the evaluation of controllability levels is described in Annex B.

Table 4 — Classes of controllability

	Class			
	C0	**C1**	**C2**	**C3**
Description	Controllable in general	Simply controllable	Normally controllable	Difficult to control or uncontrollable

5.4.3.8 Class C0 is used for hazards addressing the unavailability of the item if they do not affect the safe operation of the vehicle (e.g. some driver assistance systems). Class C0 may be assigned if dedicated regulations exist that specify the functional performance with respect to a defined hazard, and C0 is argued using the corresponding existing experience concerning sufficient controllability. If a hazard is assigned to the controllability class C0, no MSIL assignment is required.

EXAMPLE A dedicated regulation is the certification of a vehicle system with a precise definition of forces or acceleration values in the case of a failure.

5.4.4 Determination of MSIL

5.4.4.1 A MSIL shall be determined for each hazardous event using the parameters "severity", "probability of exposure" and "controllability" in accordance with Table 5.

NOTE Four MSILs are defined: MSIL A, MSIL B, MSIL C, and MSIL D, where MSIL A is the lowest safety integrity level and MSIL D the highest safety integrity level.

Table 5 — MSIL determination

Severity class	Probability class	Controllability class		
		C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B

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Table 5 *(continued)*

Severity class	Probability class	Controllability class		
		C1	C2	C3
S2	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	E1	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

5.4.5 Determination of ASIL and safety goals

5.4.5.1 The conversion of MSIL to ASIL shall be performed in accordance with Table 6, prior to the definition of the safety goals, so that applicable ISO 26262:2011 (all parts) requirements can be adopted.

NOTE 1 In addition to these three ASILs, the class QM (quality management) denotes no requirement to comply with ISO 26262:2011 (all parts).

NOTE 2 In order to adopt the necessary risk reduction requirements and safety measures contained in ISO 26262:2011 (all parts), it is important that MSIL is converted to ASIL so that the most appropriate degree of rigour is used in avoiding unreasonable residual risk associated with malfunctioning E/E items or elements used in motorcycle applications.

NOTE 3 To support the integration of this Publicly Available Standard into the ISO 26262:2011 (all parts) Edition 2, the term ASIL D has been retained within this Publicly Available Standard.

Table 6 — Conversion of MSIL to ASIL

MSIL	ASIL
QM	QM
A	QM
B	A
C	B
D	C

5.4.5.2 A safety goal shall be determined for each hazardous event with an ASIL, converted from MSIL. If similar safety goals are determined, these may be combined into one safety goal.

NOTE Safety goals are top-level safety requirements for the item. They lead to the functional safety requirements needed to avoid an unreasonable risk for each hazardous event. Safety goals are not expressed in terms of technological solutions, but in terms of functional objectives.

5.4.5.3 The ASIL, converted from MSIL, shall be assigned to the corresponding safety goal. If similar safety goals are combined into a single one, as described in 5.4.5.2, the highest ASIL shall be assigned to the combined safety goal.

NOTE If combined safety goals refer to the same hazard in different situations, then the resulting ASIL of the safety goal is the highest one of the considered safety goals of every situation.

5.4.5.4 If a safety goal can be achieved by transitioning to, or by maintaining, one or more safe states, then the corresponding safe state(s) shall be specified.

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NOTE Safe states are further elaborated in ISO 26262-3:2011, Clause 8.

EXAMPLE A safe state could be switched off, locked, vehicle stationary, and maintained functionality in the case of a failure over a defined time.

5.4.5.5 The safety goals together with their attributes (ASIL) shall be specified in accordance with ISO 26262-8:2011, Clause 6.

NOTE The safety goal can include features such as the fault tolerant time interval, or physical characteristics (e.g. a maximum level of unwanted acceleration) if they were relevant to the MSIL determination.

5.4.6 Verification

5.4.6.1 The hazard analysis, risk assessment, and the safety goals shall be verified in accordance with ISO 26262-8:2011, Clause 9, to show their

a) completeness with regard to situations (5.4.2.1) and hazards (5.4.2.2),

b) compliance with the item definition,

c) consistency with related hazard analyses and risk assessments,

d) completeness of the coverage of the hazardous events,

e) consistency of the assigned MSILs with the corresponding hazardous events, and

f) consistency of MSIL-ASIL conversion.

NOTE This verification review checks the hazard analysis and risk assessment of the item for correctness and completeness, i.e. considered situations, hazards, and parameter estimations (severity, probability of exposure and controllability). In contrast, the confirmation review of the hazard analysis and risk assessment in accordance with Clause 4, checks formally that the hazard analysis and risk assessment procedure complies with the requirements of Clause 5.

5.5 Work products

5.5.1 Hazard analysis and risk assessment resulting from the requirements of 5.4.1.1 to 5.4.2.2.4.

5.5.2 Safety goals resulting from the requirements of 5.4.5.2 to 5.4.5.5.

5.5.3 Verification review report of the hazard analysis and risk assessment and the safety goals resulting from the requirement of 5.4.6.

6 Vehicle integration and testing

6.1 Objectives

This Clause provides a tailoring of ISO 26262-4:2011, Clause 8 for motorcycles.

The vehicle integration is the integration of the item with other systems within a vehicle and with the vehicle itself.

The first objective of the integration process is to test compliance with each safety requirement in accordance with its specification and ASIL classification.

The second objective is to verify that the “system design” covering the safety requirements (see ISO 26262-4:2011, Clause 7) is correctly implemented by the entire item.

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6.2 General

The vehicle integration and testing is carried out in a systematic way starting from software-hardware integration and testing (see ISO 26262-4:2011, 8.4.2) through system integration and testing (see ISO 26262-4:2011, 8.4.3) to vehicle integration and testing. The vehicle integration and testing for motorcycles is carried out with respect to ASILs, derived from MSILs, and by considering specific characteristics of these types of vehicles.

6.3 Input to this Clause

6.3.1 Prerequisites

The following information shall be available:

— safety goals in accordance with ISO 26262-3:2011, 7.5.2;

— functional safety concept in accordance with ISO 26262-3:2011, 8.5.1;

— item integration and testing plan in accordance with ISO 26262-4:2011, 5.5.3;

— technical safety concept in accordance with ISO 26262-4:2011, 7.5.1;

— system design specification in accordance with ISO 26262-4:2011, 7.5.2;

— hardware-software interface specification (HSI) in accordance with ISO 26262-4:2011, 7.5.3.

6.3.2 Further supporting information

The following information can be considered:

— vehicle architecture (from external source);

— technical safety concepts of other vehicle systems (from external source);

— safety analysis reports (see ISO 26262-4:2011, 7.5.6).

6.4 Requirements and recommendations

6.4.1 Vehicle integration

6.4.1.1 The item shall be integrated into the vehicle and the vehicle integration tests shall be completed.

6.4.1.2 The verification of the interface specification of the item with the in-vehicle communication network and the in-vehicle power supply network shall be performed.

6.4.2 Test goals and test methods during vehicle testing

6.4.2.1 To detect systematic faults during vehicle integration, the test goals, resulting from the requirements 6.4.2.2 to 6.4.2.6, shall be addressed by the application of adequate test methods as given in the corresponding tables. The tables shall be interpreted in accordance with ISO 26262-4:2011, 4.2.

NOTE Depending on the function implemented, its complexity, or the distributed nature of the item, it can be reasonable to move test methods to other integration sub-phases with adequate rationale.

EXAMPLE If concerns over rider safety exist, it can be appropriate to select alternative test methods or move test activities to other integration sub-phases.

6.4.2.2 The correct implementation of the functional safety requirements at the vehicle level shall be demonstrated where feasible using test methods given in Table 7.

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Table 7 — Correct implementation of the functional safety requirements at the vehicle level

Methods		ASIL			
		A	B	C	D
1a	Requirement-based test[a]	++	++	++	++
1b	Fault injection test[b]	++	++	++	++
1c	Long-term test[c]	++	++	++	++
1d	User test under real-life conditions[c,d]	++	++	++	++

a A requirements-based test denotes a test against functional and non-functional requirements.

b A fault injection test uses special means to introduce faults into the item. This can be done within the item via a special test interface or specially prepared elements or communication devices. The method is often used to improve the test coverage of the safety requirements, because during normal operation, safety mechanisms are not invoked

c A long-term test and a user test under real-life conditions are similar to tests derived from field experience but use a larger sample size, normal users as testers, and are not bound to prior specified test scenarios, but performed under real-life conditions during everyday life. These test can have limitations if necessary to ensure the safety of the testers, e.g. with additional safety measures or disabled actuators. Long-term tests can be infeasible for motorcycles.

d User tests can be infeasible for motorcycles.

6.4.2.3 This requirement applies to ASIL (A), (B), C, and D, in accordance with ISO 26262-4:2011, 4.3. Where feasible, the correct functional performance, accuracy, and timing of the safety mechanisms at the vehicle level shall be demonstrated using test methods given in Table 8.

Table 8 — Correct functional performance, accuracy, and timing of safety mechanisms at the vehicle level

Methods		ASIL			
		A	B	C	D
1a	Performance test[a]	+	+	++	++
1b	Long-term test[b]	+	+	++	++
1c	User test under real-life conditions[b,c]	+	+	++	++

a A performance test can verify the performance (e.g. fault tolerant time intervals and vehicle controllability in the presence of faults) of the safety mechanisms concerning the item.

b A long-term test and a user test under real-life conditions are similar to tests derived from field experience but use a larger sample size, normal users as testers, and are not bound to prior specified test scenarios, but performed under real-life conditions during everyday life. These test can have limitations if necessary to ensure the safety of the testers, e.g. with additional safety measures or disabled actuators. Long-term tests can be infeasible for motorcycles.

c User tests can be infeasible for motorcycles.

6.4.2.4 This requirement applies to ASIL (A), (B), C, and D, in accordance with ISO 26262-4:2011, 4.3. Where feasible, the consistency and correctness of the implementation of the external interfaces at the vehicle level shall be demonstrated using test methods given in Table 9.

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Table 9 — Consistent and correct implementation of internal and external interfaces at the vehicle level

Methods		ASIL			
		A	B	C	D
1a	Test of external interfaces[a]	o	+	++	++
1b	Test of interaction/communication[b]	o	+	++	++

[a] An interface test at the vehicle level tests the interfaces of the vehicle systems for compatibility. This can be done statically by validating value ranges, ratings, or geometries, as well as dynamically during operation of the whole vehicle.

[b] A communication and interaction test includes tests of the communication between the systems of the vehicle during runtime against functional and non-functional requirements.

6.4.2.5 This requirement applies to ASIL (A), (B), C, and D, in accordance with ISO 26262-4:2011, 4.3. Where feasible, the effectiveness of the safety mechanisms' failure coverage at the vehicle level shall be demonstrated using test methods given in Table 10.

Table 10 — Effectiveness of a safety mechanism's failure coverage at the vehicle level

Methods		ASIL			
		A	B	C	D
1a	Fault injection test[a]	o	+	++	++
1b	Error guessing test[b]	o	+	++	++
1c	Test derived from field experience[c]	o	+	++	++

[a] A fault injection test uses special means to introduce faults into the vehicle. This can be done within the vehicle via a special test interface, specially prepared hardware or communication devices. The method is often used to improve the test coverage of the safety requirements, because during normal operation safety measures are not invoked.

[b] An error guessing test uses expert knowledge and data collected through lessons learned to anticipate errors in the vehicle. Then a set of tests along with adequate test facilities is designed to check for these errors. Error guessing is an effective method given a tester who has previous experience with similar vehicle applications.

[c] A test derived from field experience uses the experience and data gathered from the field. Erroneous vehicle behaviour or newly discovered operational situations are analyzed and a set of tests is designed to check the vehicle with respect to the new findings.

6.4.2.6 This requirement applies to ASIL (A), (B), C, and D, in accordance with ISO 26262-4:2011, 4.3. Where feasible, the level of robustness at the vehicle level shall be demonstrated using test methods given in Table 11.

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Table 11 — Level of robustness at the vehicle level

Methods		ASIL			
		A	B	C	D
1a	Resource usage test[a]	o	+	++	++
1b	Stress test[b]	o	+	++	++
1c	Test for interference resistance and robustness under certain environmental conditions[c]	o	+	++	++
1d	Long-term test[d]	o	+	++	++

[a] At the item level, resource usage testing is usually performed in dynamic environments (e.g. lab cars or prototypes). Issues to test include item internal resources, power consumption, or limited resources of other vehicle systems.

[b] A stress test verifies the correct operation of the vehicle under high operational loads or high demands from the environment. Therefore, tests under high loads on the vehicle or with extreme user inputs or requests from other systems, as well as tests with extreme temperatures, humidity, or mechanical shocks, can be applied.

[c] A test for interference resistance and robustness, under certain environmental conditions, is a special case of stress testing. This includes EMC and ESD tests (e.g. see References [1] and [4]).

[d] A long-term test and a user test under real-life conditions are similar to tests derived from field experience but use a larger sample size, normal users as testers, and are not bound to prior specified test scenarios, but performed under real-life conditions during everyday life. Long-term tests can be infeasible for motorcycles.

6.5 Work products

Integration testing report(s) resulting from requirements of 6.4.1 and 6.4.2.

7 Safety Validation

7.1 Objectives

This Clause provides a tailoring of ISO 26262-4:2011, Clause 9 for motorcycles.

The first objective is to provide evidence of compliance with the safety goals and that the functional safety concepts are appropriate for the functional safety of the item.

The second objective is to provide evidence that the safety goals are correct, complete and fully achieved at the vehicle level.

7.2 General

The purpose of the preceding verification activities (e.g. design verification, safety analyses, hardware, software, and item integration and testing) is to provide evidence that the results of each particular activity comply with the specified requirements.

The validation of the integrated item in representative vehicle(s) aims to provide evidence of appropriateness for the intended use and aims to confirm the adequacy of the safety measures for a class or set of vehicles. Safety validation does cover assurance, that the safety goals are sufficient and have been achieved, based on examination and tests.

7.3 Inputs to this Clause

7.3.1 Prerequisites

The following information shall be available:

— hazard analysis and risk assessment in accordance with 5.5.1;

— safety goals in accordance with 5.5.2;

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— functional safety concept in accordance with ISO 26262-3:2011, 8.5.1.

7.3.2 Further supporting information

The following information can be considered:

— project plan (refined) (see ISO 26262-4:2011, 5.5.1);

— technical safety concept (see ISO 26262-4:2011, 7.5.1);

— functional concept (from external source);

— item integration and testing plan (refined) (see ISO 26262-4:2011, 8.5.1);

— safety analysis reports (see ISO 26262-4:2011, 7.5.6).

7.4 Requirements and recommendation

7.4.1 Validation environment

7.4.1.1 The safety goals shall be validated for the item integrated in a representative vehicle.

NOTE This integrated item includes, where applicable, system, software, hardware, elements of other technologies, and external measures.

7.4.2 Planning of validation

7.4.2.1 The validation plan shall be refined, including the following:

a) the configuration of the item subjected to validation including its calibration data in accordance with ISO 26262-6:2011, Annex C;

   NOTE If a complete validation of each item configuration is not feasible, then a reasonable subset can be selected.

b) the specification of validation procedures, test cases, riding manoeuvres, and acceptance criteria;

c) the equipment and the required environmental conditions.

7.4.3 Execution of validation

7.4.3.1 If testing is used for validation, then the same requirements as provided for verification testing (see ISO 26262-8:2011, 9.4.2 and 9.4.3), can be applied.

7.4.3.2 The safety goals of the item shall be validated at the vehicle level by evaluating the following:

a) the controllability;

   NOTE Controllability can be validated using operating scenarios, including intended use and foreseeable misuse.

b) the effectiveness of safety measures for controlling random and systematic failures;

c) the effectiveness of the external measures;

d) the effectiveness of the elements of other technologies.

7.4.3.3 This requirement applies to ASILs (B), C, and D of the safety goal: the validation of the metrics for random hardware failures shall be carried out at the item level for:

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a) the evaluation of safety goal violations due to random hardware failures as determined in ISO 26262-5:2011, Clause 9, against the target values as defined by requirement ISO 26262-4:2011, 7.4.4.3;

b) the evaluation of the hardware architectural metrics in accordance with the assessment criteria of ISO 26262-5:2011, Clause 8, against the target values as defined by requirement ISO 26262-4:2011, 7.4.4.2.

NOTE Quantitative evaluation for elements of the item is defined in ISO 26262-5:2011, 9.4.2 and 9.4.3. The whole item is evaluated qualitatively in case other technologies are involved in the item.

7.4.3.4 The validation at the vehicle level, based on the safety goals, the functional safety requirements, and the intended use, shall be executed as planned using the following:

a) the validation procedures and test cases for each safety goal including detailed pass/fail criteria;

b) the scope of application. This may include issues such as configuration, environmental conditions, riding situations, operational use cases, etc.

NOTE Operational use cases can be created to help focus the safety validation at the vehicle level.

7.4.3.5 An appropriate set of the following methods shall be applied:

a) repeatable tests with specified test procedures, test cases, and pass/fail criteria;

EXAMPLE 1 Positive tests of functions and safety requirements, black box testing, simulation, tests under boundary conditions, fault injection, durability tests, stress tests, highly accelerated life testing (HALT), simulation of external influences.

b) analyses;

EXAMPLE 2 FMEA, FTA, ETA, simulation.

c) long-term tests, such as vehicle driving schedules and captured test fleets;

NOTE 1 Long-term tests with targeted users can be infeasible for motorcycles.

d) user tests under real-life conditions, panel or blind tests, expert panels; and

NOTE 2 User test can be infeasible for motorcycles. Real-life condition can be conducted using simulated condition.

e) reviews.

7.4.4 Evaluation

7.4.4.1 The results of the validation shall be evaluated.

7.5 Work products

7.5.1 Validation plan (refined) resulting from requirement 7.4.2.

7.5.2 Validation report resulting from requirements 7.4.3 and 7.4.4.

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Annex A
(informative)

Hazard analysis and risk assessment for motorcycles

A.1 General

This Annex gives a general explanation of the hazard analysis and risk assessment. The examples in A.2 (severity), A.3 (probability of exposure), and A.4 (controllability) are for information only and are not exhaustive.

For this analytical approach, a risk (R) can be described as a function (F), with the frequency of occurrence (f) of a hazardous event, the ability to avoid specific harm or damage through timely reactions of the persons involved, that is controllability (C), and the potential severity (S) of the resulting harm or damage:

$$R = F\,(f, C, S)$$

The frequency of occurrence (f) is, in turn, influenced by several factors. One factor to consider is how frequently and for how long individuals find themselves in a situation where the aforementioned hazardous event can occur. In this Publicly Available Standard, this is simplified to be a measure of the probability of the riding scenario taking place in which the hazardous event can occur (exposure: E). Another factor is the failure rate of the item that could lead to the hazardous event (failure rate: λ). The failure rate is characterized by hazardous hardware random failures and systematic faults that remained in the system:

$$f = E \times \lambda$$

Hazard analysis and risk assessment is concerned with setting requirements for the item such that unreasonable risk is avoided.

The MSILs and resultant ASILs that result from the hazard analysis and risk assessment determine the minimum set of requirements on the item, in order to control or reduce the probability of random hardware failures, and to avoid systematic faults. The failure rate of the item is not considered *a priori* (in the risk assessment) because an unreasonable residual risk is avoided through the implementation of the resulting safety requirements.

The hazard analysis and risk assessment sub-phase comprises three steps.

a) Situation analysis and hazard identification (see 5.4.2): The goal of the situation analysis and hazard identification is to identify the potential unintended behaviours of the item that could lead to a hazardous event. The situation analysis and hazard identification activity requires a clear definition of the item, its functionality, and its boundaries. It is based on the item's behaviour; therefore, the detailed design of the item does not necessarily need to be known.

EXAMPLE Factors to be considered for situation analysis and hazard identification can include the following:

— vehicle usage scenarios, for example high speed and urban operation, parking and off-road;

— environmental conditions, for example road surface friction, side winds;

— reasonably foreseeable rider use and misuse;

— interaction between operational systems.

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b) Classification of hazardous events (see 5.4.3): The hazard classification scheme comprises the determination of the severity, the probability of exposure, and the controllability associated with the hazardous events of the item. The severity represents an estimate of the potential harm in a particular riding situation, while the probability of exposure is determined by the corresponding situation. The controllability rates how easy or difficult it is for the rider or other road traffic participant to avoid the considered accident type in the considered operational situation. For each hazard, depending on the number of related hazardous events, the classification will result in one or more combinations of severity, probability of exposure, and controllability.

c) MSIL determination (see 5.4.4): Determining the required motorcycle safety integrity level.

A.2 Examples of severity

A.2.1 General

The potential injuries, as a result of a hazard, are evaluated for the rider, passengers, and people around the vehicle, or to individuals in surrounding vehicles to determine the severity class for a given hazard. From this evaluation, the corresponding severity class is then determined for example as shown in Table A.1.

Table A.1 presents examples of consequences which can occur for a given hazard and the corresponding severity class for each consequence.

Because of the complexity of accidents and the many possible variations of accident situations, the examples provided in Table A.1 represent only an approximate estimate of accident effects. They represent expected values based on previous accident analyses. Therefore, no generally valid conclusions can be derived from these individual descriptions.

Accident statistics can be used to determine the distribution of injuries that can be expected to occur in different types of accidents.

In Table A.1, AIS represents a categorisation of injury classes, but only for single injuries. Instead of AIS, other categorisations such as Maximum AIS (MAIS) and Injury Severity Score (ISS) can be used.

The use of a specific injury scale depends on the state of medical research at the time the analysis is performed. Therefore, the appropriateness of the different injury scales, such as AIS, ISS, and NISS, can vary over time (see References [5],[7], and [8]).

Table A.1 — Examples of severity classification

	Class of Severity			
	S0	**S1**	**S2**	**S3**
Description	No injuries	Light and moderate injuries	Severe injuries, possibly life-threatening, survival probable	Life-threatening injuries (survival uncertain) or fatal injuries
Reference for single injuries (from AIS scale)	AIS 0 and less than 10 % probability of AIS 1-6 Damage that cannot be classified safety-related	more than 10 % probability of AIS 1-6 (and not S2 or S3)	more than 10 % probability of AIS 3-6 (and not S3)	more than 10 % probability of AIS 5-6
Informative examples	Falling alone/loss of balance.	Collision with road-side infrastructure/stationary vehicle at typical urban vehicle speeds.	Collision with road-side infrastructure/stationary vehicle at typical main road vehicle speeds.	Collision with road-side infrastructure/stationary vehicle at typical highway vehicle speeds.

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Table A.1 *(continued)*

	Class of Severity			
	S0	**S1**	**S2**	**S3**
	Collision with road-side infrastructure/stationary vehicle at walking speed.	Impact with pedestrian/ cyclist at typical walking speed.	Impact with pedestrian/ cyclist at typical urban vehicle speeds.	Impact with pedestrian/ cyclist at typical main road vehicle speeds.
	Rear collision (passenger car into rear of motorcycle) with differential speed equivalent to typical walking speed.	Low side fall at typical urban/main road vehicle speeds with no subsequent impact.	Low side fall at typical highway vehicle speeds with no subsequent impact.	Side collision (passenger car into side of motorcycle) at typical main road vehicle speed.
		High side fall at typical urban road vehicle speeds with no subsequent impact.	High side fall at typical main road/ highway vehicle speeds with no subsequent impact.	Rear collision (passenger car into rear of motorcycle) with differential speed equivalent to typical highway vehicle speed.
		Side collision (passenger car into side of motorcycle) at typical walking speed.	Side collision (passenger car into side of motorcycle) at typical urban vehicle speed.	Front collision into an oncoming passenger car with differential speed equivalent to typical main road/highway vehicle speed.
		Rear collision (passenger car into rear of motorcycle) with differential speed equivalent to typical urban vehicle speed.	Rear collision (passenger car into rear of motorcycle) with differential speed equivalent to typical main road vehicle speed.	
		Front collision into an oncoming passenger car with differential speed equivalent to typical walking speed.	Front collision into an oncoming passenger car with differential speed equivalent to typical urban vehicle speed.	

A.2.2 Description of the AIS stages

To describe the severity, the AIS classification is used. The AIS represents a classification of the severity of injuries and is issued by the Association for the Advancement of Automotive Medicine (AAAM) (see Reference [5]). The guidelines were created to enable an international comparison of severity. The scale is divided into seven classes:

— AIS 0: no injuries;

— AIS 1: light injuries such as skin-deep wounds, muscle pains, whiplash, etc.;

— AIS 2: moderate injuries such as deep flesh wounds, concussion with up to 15 minutes of unconsciousness, uncomplicated long bone fractures, uncomplicated rib fractures, etc.;

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— AIS 3: severe but not life-threatening injuries such as skull fractures without brain injury, spinal dislocations below the fourth cervical vertebra without damage to the spinal cord, more than one fractured rib without paradoxical breathing, etc.;

— AIS 4: severe injuries (life-threatening, survival probable) such as concussion with or without skull fractures with up to 12 hours of unconsciousness, paradoxical breathing;

— AIS 5: critical injuries (life-threatening, survival uncertain) such as spinal fractures below the fourth cervical vertebra with damage to the spinal cord, intestinal tears, cardiac tears, more than 12 hours of unconsciousness including intracranial bleeding;

— AIS 6: extremely critical or fatal injuries such as fractures of the cervical vertebrae above the third cervical vertebra with damage to the spinal cord, extremely critical open wounds of body cavities (thoracic and abdominal cavities), etc.

A.3 Examples and explanations of the probability of exposure

An estimation of the probability of exposure requires the evaluation of the scenarios in which the relevant environmental factors that contribute to the occurrence of the hazard are present. The scenarios to be evaluated include a wide range of riding or operating situations.

These evaluations result in the designation of the hazard scenarios into one of five probability of exposure classifications, given the nomenclature E0 (lowest exposure level), E1, E2, E3, and E4 (highest exposure level).

The first of these, E0, is assigned to situations which, although identified during a hazard and risk analysis, are considered to be unusual or incredible. Subsequent evaluation of the hazards associated exclusively with these E0 scenarios can be excluded from further analysis.

EXAMPLE Typical examples of E0 include the following:

a) a very unusual, or infeasible, co-occurrence of circumstances, e.g.

- vehicle involved in an accident with another vehicle that is carrying a hazardous material (note this does not apply to a vehicle which is designed to carry that material), or

- vehicle involved in an incident which includes an aeroplane landing on a highway;

b) natural disasters, e.g. earthquake, hurricane, forest fire.

The remaining E1, E2, E3, and E4 levels are assigned for situations that can become hazardous depending on either the duration of a situation (temporal overlap) or the frequency of occurrence of a situation.

NOTE 1 The classification can depend on e.g. geographical location or type of use (see 5.4.3.4).

In the first case, where the exposure is ranked based on the duration of a situation, the probability of exposure is typically estimated by the proportion of total operating time (ignition on). In special cases, the total operating time can be the vehicle life-time (including ignition off). Table A.2 gives examples of these durational situations classifications and the typical exposure rankings.

NOTE 2 A hazard can be related to the duration of a given scenario (e.g. the average time spent negotiating traffic intersections), while another hazard can be related to the frequency of this same scenario (e.g. the rate of repetition with which a vehicle negotiates traffic intersections).

Alternately, some exposure estimations can be determined more appropriately by using the frequency of occurrence of a related riding situation. In these circumstances, pre-existing system faults lead to the hazardous event within a short interval after the situation occurs. Examples of these riding situations and typical exposure rankings are given in Table A.3.

A riding situation can have both duration and a frequency, such as riding in a parking lot. In this case, the examples in Table A.2 and A.3 might not lead to the same exposure category, so the most appropriate exposure rank is selected for the analysis of the considered riding scenario.

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Table A.2 — Classes of probability of exposure regarding duration in operational situations

	Class of probability of exposure in operational situations			
	E1	**E2**	**E3**	**E4**
Description	Very low probability	Low probability	Medium probability	High probability
Duration (% of average operating time)	Not specified	<1 %	1 % - 10 %	>10 %
Informative Examples (Event)	Large lean angle	Intermediate lean angle	Small lean angle	Slight lean angle or less
	In the process of jump/bump starting bike	Refuelling	Passing (other vehicles)	Cruising
		Performing a hill-start		EV bike plug-in recharging
	Engine starting		Accelerating	
		Using directional indicators		Parked (incl. bike on centre/side stand)
	Using side stand (up or down)		Decelerating	
		Pulling out of an intersection	Engine idling, motorcycle on stand	
	Emergency braking			
	Riding across rail or tram tracks	Performing an overtaking manoeuvre	Stopped at traffic light or intersection	
	Negotiating lost cargo or obstacle in lane of travel (public road)	Pulling away from a stand-still		
		Braking		
	Shifting transmission gears			
		Normal cornering		
		In a tunnel		
		Feet down motorcycle balancing and manoeuvring		

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Table A.3 — Classes of probability of exposure regarding frequency in operational situations

		Class of probability of exposure in operational situations			
		E1	**E2**	**E3**	**E4**
Description		Very low probability	Low probability	Medium probability	High probability
Frequency of Situation		Occur less often than once a year for the great majority of riders	Occur a few times a year for the great majority of riders	Occur once a month or more often for an average riders	Occur during almost every ride on average
Informative Examples	**Road layout**	Off-road/ uncategorized roads	Mountain roads Cobbled roads (pave) Roundabout	Motorway/ Highway (incl. divided)	Secondary road Urban road
	Road surface/ riding conditions	Snow and ice on road	Riding on low friction (leaves, loose stones, oil, diesel, mud) Riding in heavy rain Unexpected sidewinds Uneven road surfaces Fog	Riding in rain/ mist Wet roads Riding across rail or tram tracks Speed humps/ speed reduction corrugations	—
	Environment/infrastructure	Lost cargo or obstacle in lane of travel (public road)	In a tunnel	Traffic congestion In a fuel station forecourt Unlit roads at night (riding in the dark)	—
	Bike stationary state	In the process of jump/ bump starting bike	In repair garage	Refuelling	Engine starting Using side stand (up/ down) Parked (incl. bike on centre/side stand) Feet down motorcycle balancing and manoeuvring Engine idling, MC on stand Stopped at traffic light or intersection
	Manoeuvre	Large lean angle Intentional front wheel lift (wheelie)	Intermediate lean angle Urgent braking	Small lean angle Performing a hill-start	Slight lean angle or less Using directional indicators

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Table A.3 *(continued)*

		Class of probability of exposure in operational situations			
		E1	E2	E3	E4
		Intentional rear wheel lift (stoppie)	Overtaking (low performance motorcycle) Manoeuvring through several stationary or moving cars Evasive manoeuvre, deviating from desired path Executing a curve at high lateral acceleration Minor front wheel lift Minor rear wheel lift		Pulling out of an intersection Passing other vehicles Overtaking Pulling away from a stand-still Accelerating Braking Decelerating Cruising Normal cornering EV bike plug-in recharging Shifting transmission gears

If the time period in which a failure remains latent is comparable to the time period before the hazardous event can be expected to take place, then the estimation of the probability of exposure considers that time period. Typically, this will concern devices that are expected to act on demand, e.g. airbags.

In this case, the probability of exposure is estimated by $\sigma * T$ where; σ is the rate of occurrence of the hazardous event and T is the duration that the failure is not perceived (possibly up to the lifetime of the vehicle). This approximation $\sigma * T$ is valid when this resulting product is small.

NOTE 3 With regard to the duration of the considered failure, the hazard analysis and risk assessment does not consider safety mechanisms that are part of the item (see 5.4.1.2).

A.4 Examples of controllability (chances to avoid harm)

The determination of the controllability class, for a given hazard, requires an estimation of the probability that the representative rider will be able to retain or regain control of a vehicle if a given hazard were to occur.

This probability estimation involves the consideration of the likelihood that representative rider will be able to retain or regain control of the vehicle if the hazard were to occur, or that individuals in the vicinity or the situation will contribute to the avoidance of the hazard by their actions. This consideration is based on evaluation of the control actions necessary by the individuals involved in the hazard scenario to retain or regain control of the situation, as well as the representative riding behaviours of the rider involved (which can be related to the target market, individuals' age, skill level, riding experience, cultural background, etc.).

NOTE 1 Controllability estimations can be influenced by a number of factors including the cultural background of the analyst, the target market for the vehicle, or rider profiles for the target market.

To aid in these evaluations, Table A.4 provides examples of riding situations in which a malfunction is introduced and the assumptions about the corresponding control behaviours that would avoid harm.

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These situations are mapped to the controllability rankings, clarifying the 90 % and 99 % breakpoints levels for judging participant controllability.

NOTE 2 The controllability classification examples provided in Table A.4 are assumed to be based on a mid-sized motorcycle intended for road use. The informative examples provided will be reviewed with respect to the type and performance of motorcycle under consideration.

NOTE 3 Table A.4 provides indications on possible hazards which can occur and to whom it is necessary to make reference when evaluating a specific item.

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Table A.4 — Examples of possibly controllable hazardous events by the rider or by the persons potentially at risk

	Class of controllability			
	C0	**C1**	**C2**	**C3**
Description	Controllable in general	Simply Controllable	Normally Controllable	Difficult to Control or Uncontrollable
Riding Factors and Scenarios	Controllable in general	99 % or more of all riders or other traffic participants are usually able to avoid harm	90 % or more of all riders or other traffic participants are usually able to avoid harm	Less than 90 % of all riders or other traffic participants are usually able, or barely able, to avoid harm
Hazard	**Operational situation (*control actions by rider/persons potentially at risk*)**			
Loss of traction (loss of lateral and/or longitudinal tyre force)	while accelerating from a standstill (*declutch, cancel acceleration*)	—	—	while accelerating during a banking manoeuvre (*cancel acceleration, counter steer, brake*)
Undemanded acceleration (equivalent to wide open throttle)	—	—	in congested urban traffic (*apply brakes, declutch*)	—
Undemanded deceleration (equivalent to engine braking)	in congested urban traffic (riders can declutch, other vehicle users can apply brakes)	during a cornering manoeuvre (*riders can declutch*)	—	—
Undemanded (maximum) braking (not locked wheels)	—	in congested urban traffic (other vehicle users can apply brakes)	—	during a cornering manoeuvre (*counter steer, weight shift*)
Loss of tractive power	whilst cruising on a highway (*brake and steer to side of road*)	during an overtaking manoeuvre (brake and steer to cancel overtaking manoeuvre)	—	—
Undemanded rear wheel lock	—	when approaching a stop junction (*steer and apply front brake*)	—	—
Undemanded front wheel lock	—	—	—	when approaching a stop junction (*weight shift*) during a cornering manoeuvre (*steer, weight shift*)
Complete loss of braking	—	—	when approaching a pedestrian crossing (steer around pedestrian, down shift, sound horn, pedestrian can avoid motorcycle)	—

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Table A.4 *(continued)*

	Class of controllability			
	C0	**C1**	**C2**	**C3**
Rollaway	while on an incline (apply brake, accelerate)	—	—	—
Loss of forward illumination	—	whilst riding on an unlit rural road at night (slow down or stop if necessary, switch on alternative lighting if available, e.g. high beam)	—	—
Loss of steering damping	—	on uneven road surfaces at highway speeds (*increase steering activity, reduce speed*)	—	—
Excessive steering damping	—	during an overtaking manoeuvre (*apply more steering force, reduce speed or stop*) while manoeuvring in a car park (apply more steering force, reduce speed or stop)	—	—
Unexpected pitching	—	when approaching a stop junction (*weight shift*) when accelerating from a standstill (*weight shift, reduce speed*)	—	—

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Annex B
(informative)

Example of controllability classification techniques

B.1 General

This Annex provides a general introduction to some recognized techniques that can be used to assist with the assignment of the controllability class for motorcycle specific hazardous events. This Annex also introduces the concept of using a Controllability Classification Panel (CCP), which assigns controllability class considering the results of evaluation and the output from controllability evaluation techniques.

This Annex does not provide guidance on how to select the controllability class for specific hazardous events, but rather focuses on the available methodologies and techniques that can be used to assist with controllability evaluation.

B.2 Concept of controllability classification panel

The assignment of the controllability class can be performed by a CCP, which can have expertise in the areas of the following:

— evaluation of motorcycle controllability [performed by expert rider(s)];

— motorcycle dynamics;

— electrical/electronic system;

— functional safety; or

— rider behaviour.

Motorcycle manufacturers and E/E system suppliers can be allowed the flexibility to tailor the numbers and make-up of the CCP on a project by project basis. A suitable rationale can be provided for the CCP selected. Involved organizations can share the role of forming a CCP as part of any functional safety planning activity in the safety lifecycle. During the concept phase, it is allowable for the CCP to perform evaluations of the controllability classification for particular hazardous events, provided a rationale supports the selection.

Evaluations by the CCP can be based on a common understanding of classifications for severity, exposure and controllability during the hazard analysis and risk assessment, the results from previous safety validation tests, previous safety analyses, the functional safety objectives, and available documentation, as well as an understanding of the representative riders' abilities and the intended use of the motorcycle. A single technique or an appropriate combination of the techniques described below, or others, can be used to confirm controllability evaluations during the hazard analysis and risk assessment.

B.3 Evaluating controllability of motorcycle hazardous events

The evaluation of controllability is an estimate of the probability, that if a hazardous event occurs, representative riders would be able to retain or regain control of the motorcycle, or other persons potentially at risk would be able to gain sufficient control of the hazardous event, such that they would be able to avoid specific harm. An evaluation can be accomplished experimentally or analytically.

Historically, automotive hazardous events have been assessed for controllability initially by evaluation based on the responses of the representative driver or other persons potentially at risk. This can

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involve, where allowable, groups of representative drivers to make an evaluation on the level of vehicle controllability when electrical/electronic (E/E) system malfunctions are introduced.

Since the dynamic behaviour of a motorcycle places far more emphasis on human interaction to ensure stability, intended trajectory and composure compared to passenger car dynamics, it is not always possible to evaluate controllability in the same way as the automotive industry. Furthermore, representative control behaviours of riders can differ substantially from those of passenger car drivers; therefore, a motorcycle specific evaluation is necessary.

As such, one evaluation approach is to make an evaluation of controllability based on feedback from actual riders in order to understand how motorcycle stability, trajectory, and composure can be influenced as a result of the rider's responses (e.g. by counter steering, throttling, braking, and weight shifting). Therefore, one generally accepted method to evaluate controllability of motorcycle hazardous events is to use expert riders to make a judgement on how a representative rider would have coped with a specific hazardous event. Expert riders have the experience and skill to handle some fairly extreme hazardous events. Use of expert riders can however be subject to appropriate controls to ensure his/her safety.

B.4 Expert riders

This Annex does not require that expert riders be certified to any particular standard or hold a particular type of advanced riding licence, but rather recommends that vehicle manufacturers, test organizations, and/or suppliers select expert riders based on their own internal procedures, which places the safety of the expert rider as the highest priority and calls for adequate risk reduction controls to be in place to minimize the risk of harm to the expert rider(s). Company procedures can include guidance on how to select expert riders. The following informative examples can be used for expert rider selection criteria:

— experience in motorcycle riding for several years in all target group relevant situations and environmental conditions;

— knowledge of using company specific standardized classification of controllability;

— experienced in accomplishing evaluations;

— capability to translate the test results to representative riders;

— technical ability to discuss the test and the results in terms of technical background;

— participation on company specific rider training courses; or

— holds an official statement as expert rider by the company.

B.5 Controllability evaluation techniques

The assignment of the controllability class, made by the CCP, can be made using an appropriate combination of common evaluation techniques such as, for example, through a group of representative or expert riders, using riding simulators or mathematical modelling techniques. If there are situations where the safety of the expert rider cannot be assured, the highest controllability class would be assigned (i.e. where a particular manoeuvre is considered uncontrollable even by an expert rider). No particular controllability evaluation technique is preferred and no specific recommendation is made as to which techniques can be used. The following techniques can be considered.

a) Evaluation by a group of representative riders

This remains a common method used within the automotive industry, and there can be examples where the risk is acceptably low for this type of evaluation to be useful, i.e. where hazardous events do not affect stability, intended trajectory, and composure of the motorcycle (e.g. electronically controlled grip heaters).

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b) Evaluation by expert riders

It is a commonly adopted technique to use evaluations by expert riders. Expert riders can make a judgement on how a representative rider would have coped with a particular hazardous event. It can be useful to use more than one expert rider to evaluate controllability (see B.6).

c) Evaluation using riding simulators

This approach could use typical riders and a riding simulator capable of providing a sufficiently realistic representation of the motorcycle dynamic control properties and riding environment when subject to an E/E system malfunction situation. Note that the word “simulator” in this context implies the use of a human rider controlling a physical, electro-mechanical dynamic representation of a motorcycle using handlebars, throttle, brakes, etc. The simulator can have suitable control feel characteristics and appropriate perceptual displays. The function of the simulator can be tailored for the purposes of the controllability evaluation.

d) Evaluation using mathematical modelling and simulation techniques

This computer simulation method uses mathematical models of the motorcycle dynamics and rider/controller. Note that the word “simulation” in this context implies a software representation of both the motorcycle and rider/controller and their dynamic interaction.

B.6 Evaluating controllability

Evaluation of representative riders’ controllability classification can be done on the basis of the following:

— vehicle response and performance as shown, for example, in Table B.1;

— awareness as shown, for example, in Table B.2; or

— control behaviour as shown, for example, in Table B.3.

Table B.1 — Vehicle response and performance

More controllable	⟵	⟶	Less controllable
There is no change in vehicle response and performance	There is a slight change in vehicle response and performance	There is a moderate change in vehicle respo nse and performance	There is a substantial change in vehicle response and performance

Table B.2 — Awareness

More controllable	⟵	⟶	Less controllable
The hazard and resulting vehicle response is imperceptible or has no effect on the operation of the vehicle. (e.g. Sound volume of radio)	The hazard and resulting vehicle response is perceptible but does not alarm the rider. The timing of the rider’s control actions can have a small effect.	The hazard and resulting vehicle response is perceptible and can alarm the rider. The timing of the rider’s control actions is important, but not critical.	The hazard and resulting vehicle response is perceptible and can substantially alarm the rider. The timing of the rider’s control actions is critical.

Table B.3 — Control behaviour

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More controllable	⟷		Less controllable
It is not necessary for the rider to change his/her control behaviour.	Normal compensatory control actions[a] are adequate for the rider to maintain control of the vehicle.	The rider can need to adapt his/her control behaviour beyond normal compensatory control actions to maintain control of the vehicle.	Extraordinary skill and or unusually high control force effort is necessary to maintain control of the vehicle.
[a] Normal compensatory control actions means a range of operating force, effort or other control action needed to control a motorcycle subjected to typical disturbances, such as wind gusts, rough road surfaces, etc.			

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