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Road vehicles — Prospective safety performance assessment of pre-crash technology by virtual simulation —

Part 2:
Guidelines and requirements for application

Véhicules routiers — Évaluation prospective de la performance sécuritaire des systèmes de pré-accident par simulation numérique —

Partie 2: Lignes directrices et exigences pour la mise en œuvre

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Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 36, *Safety and impact testing*.

A list of all parts in the ISO 21934 series can be found on the ISO website.

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

Active safety and advanced driver assistance systems (ADAS), collectively referred to in this document as active safety technologies, as well as automated driving technology have recently been introduced into the market. Their development raises questions about the extent to which these technologies prevent crashes and their ensuing injuries. These questions are of relevance to stakeholders such as vehicle manufacturers and suppliers, road authorities, research organisations and academia, politicians, insurance companies as well as consumer organisations.

The answers to these questions are derived from assessing the technology in terms of road traffic safety. There is a number of assessment methodologies in use (see ISO/TR 12353-4). In general, the current methodologies are divided into two types: retrospective assessments and prospective assessments. Retrospective methods determine the technology's safety effect after its market introduction based on accident data. A precondition for these methods is that sufficient accident cases with and without the technology have been recorded for a comparison in a certain vehicle subgroup or class. Prospective methods, on the other hand, predict the technology's safety effect before its market introduction.

This document focuses on the prospective assessment of traffic safety for vehicle-integrated technologies acting in the pre-crash phase by means of virtual simulation.

The safety performance of a technology is determined by comparing data from the baseline and treatment simulations. The baseline for the assessment is the simulation without the vehicle-integrated technology while the treatment is the simulation with the technology.

The assessment method that is described in this document is limited to vehicle-integrated technology and does not consider technologies operating off-board. The virtual simulation method per se is not limited to a certain vehicle type. Furthermore, the assessment approach discussed in this document focuses on crash avoidance and the technology's contribution to the mitigation of the consequences. Safety technologies that act in the in-crash phase or the post-crash phase are not explicitly addressed by the method, although the output from prospective assessments of crash avoidance technologies can be considered as an important input to determine the consequences of these technologies.

In general, the assessment of active safety technologies requires consideration of the interaction with surrounding traffic as well as the driver of the vehicle under test. Consequently, for a comprehensive assessment, the technology's safety performance must be analysed in a multitude of scenarios to cover all relevant circumstances that affect the critical situation. The virtual simulation approach allows for running large numbers of cases and offers a promising combination of flexibility, reproducibility and experimental control in the assessment of safety performance. The need for virtual simulations in the prospective assessment of safety technologies is generally recognized. This will have a positive impact on the comparability of results by virtual assessment.

The state of the art with respect to prospective safety performance assessment is described in ISO/TR 21934-1, which builds the foundation of this document.

Road vehicles — Prospective safety performance assessment of pre-crash technology by virtual simulation —

Part 2:
Guidelines and requirements for application

1 Scope

This document specifies methods, guidelines and their application for prospective safety performance assessment of pre-crash technologies in road vehicles by virtual simulation. The purpose of the document is to provide prerequisites for the procedures to achieve comparable results among different safety performance assessments and tools.

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 8855, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ISO 12353-1, *Road vehicles — Traffic accident analysis — Part 1: Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12353-1 and the following apply.

ISO and IEC maintain terminological 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
baseline
set of data to which the performance of the technology under study is compared when performing prospective assessments of performance of technologies

3.2
simulation block
grouping of at least two simulation models that are related to each other in terms of topic

3.3
collision
road vehicle accident event in which a vehicle strikes, or is struck by, another vehicle, road user or obstacle (on or off the road), with ensuing damage and/or injury

Note 1 to entry: In simulation, a collision is typically detected once the volumes of two objects overlap in an infinitely small manner.

[SOURCE: ISO 6813:1998, 3.3, modified — Note 1 to entry added.]

3.4
conflict
situation in which at least two road users are involved and which leads to a collision in the near future if no actions is taken

Note 1 to entry: The definition of conflict is based on Reference [8].

3.5
data point
set of one or more discrete measurements on a single member of a unit of interest

EXAMPLE Vehicle mass and velocity.

3.6
data series
description of multiple data points that are linked via another type of information

EXAMPLE The velocity over time measured during the simulation for the centre of gravity of the vehicle under test.

Note 1 to entry: Typically, the type of information that links the data points is time.

3.7
deterministic simulation model
model that produces the same result when simulated twice with the same inputs and parameter values

3.8
distribution-based pre-simulation model
model that includes a distribution for at least one of the simulation parameters defined by the pre-simulation model

Note 1 to entry: Most pre-simulation models are distribution-based. The following are examples of distribution-based simulation models:

EXAMPLE 1 A simulation parameter (e.g. the road friction coefficient or a system parameter such as maximum intervention deceleration) is sampled at specific values within a range and a simulation is run for each of these parameter values.

EXAMPLE 2 Like EXAMPLE 1, but with a nonuniform distribution for the simulation parameter (e.g. driver brake reaction time). A simulation parameter, such as Monte Carlo, is sampled for each simulation run from a probability distribution (either defined on a closed mathematical form, such as a lognormal distribution, or defined as an empirical, numerical distribution).

EXAMPLE 3 Like EXAMPLE 2, but instead of a Monte Carlo-style draw, only one simulation is carried out per simulation parameter's bin in an empirical distribution. The simulation results are weighted accordingly in a post-processing step.

Note 2 to entry: If a pre-simulation model is not distribution-based, it transforms parameters provided by the simulation framework user to other parameters needed by the simulation model (e.g., simple unit conversions or calculating model update matrices for a linear vehicle model from parameters specifying vehicle mass, tire stiffnesses, etc).

3.9
driver
vehicle occupant in actual control of a vehicle, or who was in control before that control was lost or taken over by a technology

3.10
event
state change at a certain point in time

3.11
injury risk function
description of the probability of an injury or fatality in relation to collision attributes

Note 1 to entry: The most frequently used injury risk functions describe the probability of an injury of a specific severity in relation to collision severity, for example impact velocity or change of velocity during collision.

3.12
in-simulation model
model that is part of the simulation framework and is updated for each time-step in the simulation

3.13
model
covers at least one (physical) domain (e.g. mechanical or electronic) and can consist of different process steps and calculations

Note 1 to entry: A simulation model can also be a container to a collection of simulation models.

3.14
non-deterministic simulation model
model that can produce different results between simulations even when inputs and parameters are constant

Note 1 to entry: Non-deterministic simulation models are often probabilistic, including some form of random draw occurring during the simulation. A probabilistic model becomes deterministic if the random seeds are assigned fixed values.

3.15
penetration rate
number of vehicles of a certain type equipped with the technology under assessment compared to the total number of vehicles of that type in a certain geographic area

3.16
probability distribution
function that describes the probabilities of outcomes of a random event

Note 1 to entry: A probability distribution of a sufficiently large sample size can be used to make inferences about the distribution of a population.

3.17
pre-crash phase
time phase immediately prior to the crash

Note 1 to entry: This phase ends with the contact between participants or objects involved in the crash.

Note 2 to entry: In this document, the pre-crash phase covers normal driving and critical situations up to the point of contact.

3.18
pre-simulation model
model that is part of the simulation framework outside of the simulation over time

Note 1 to entry: Such models are used to determine and set parameters for the in-simulation models.

3.19
projection
estimation of time or space changes for a population or target area based on the results of a smaller sample of input data

Note 1 to entry: A projection can be conducted either in time or space or in both dimensions. The time projection is an estimation of (future) changes for a population based on the results of a reference period. The space projection is an estimation of changes for a target area based on the results of a smaller sample/subset of input data.

3.20
prospective assessment
predictive assessment of the future performance of given technologies before their deployment into a vehicle population

3.21
real-world data
data collected in a non-virtual situation and environment

3.22
representative
sample that is an available subset of a population

Note 1 to entry: The sample is representative of the population for a set of features if their statistical characteristics (e.g. proportion, distribution) match those of the entire population.

3.23
research question
question that a research project is designed to answer

Note 1 to entry: A research question defines the scope of a prospective safety performance assessment by simulation.

3.24
retrospective assessment
assessment of the past performance of given technologies after their deployment into a vehicle population

3.25
safety critical event
SCE
conflict or series of related conflicts that involves the subject vehicle either alone or in combination with another vehicle, pedal cyclist, pedestrian, object or road edge

Note 1 to entry: This document describes the range of conflict types that may comprise an SCE and an SCE may be composed of a single conflict type or multiple simultaneous or sequential conflict types. Conflicts should be non-intentional and non-premeditated (unplanned) by at least one conflict partner.

[SOURCE: ISO/TR 21974-1:2018, 3.13]

3.26
safety performance
quantified capability of a technology to achieve an improvement in road traffic safety

3.27
scenario
description of the traffic, infrastructure and environmental conditions (e.g. weather and lighting conditions) for the simulation that consists of a time sequence of scenes

Note 1 to entry: A scenario is limited in terms of time and space.

Note 2 to entry: A scene describes a snapshot that encompasses the mobile and immobile elements of the traffic, infrastructure and environmental conditions, the self-representation of all actors and observers and the relations between these elements.

3.28
scenario category
selection of scenarios that share one or more characteristics

3.29
severity
estimate of the extent of harm to one or more individuals or of property damage that can occur in a potential collision

3.30
simulation
enactment of a situation with artificial conditions, typically performed by updating models over discrete time steps

3.31
simulation framework
aggregate of all components in a simulation including all simulation blocks and models

Note 1 to entry: Process steps outside the simulation (e.g. post processing) are not part of the simulation framework.

3.32
traffic agent
anyone who uses a road including sidewalk and other adjacent spaces

3.33
technology
collection of vehicle-implemented techniques, processes and systems capable of temporarily or permanently taking control of the vehicle and from which the expected safety benefit is predicted in the prospective assessment

3.34
test
use of quantitative measures to evaluate technology under a set of specified conditions, with reference to values that represent an acceptable outcome

3.35
treatment
use of a specific technology to affect the course of events in a scenario to avoid or mitigate crashes when performing prospective assessments of performance of technologies

Note 1 to entry: Treatment simulations provide data on the performance of the technology under assessment to compare with baseline data.

Note 2 to entry: See 3.1.

3.36
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

Note 1 to entry: For the prospective safety performance assessment, it is important that the results of the virtual assessment are reliable (i.e. the results are reproducible under the same conditions) and trustable (i.e. the results are consistent with the real-world safety performance of the technology).

3.37
vehicle under test
VuT
vehicle that is focused on in the safety performance assessment

Note 1 to entry: In the treatment, this vehicle is equipped with the technology under assessment.

3.38
verification
confirmation through the provision of objective evidence that (internal) requirements of the safety performance assessment process and tool (including methods and models) have been fulfilled

4 Symbols and abbreviated terms

4.1 Symbols

E_{EES}	energy equivalent speed
E_{def}	kinetic energy dissipated by the vehicle during the contact phase by deformation
$I_{Baseline,i}$	severity of (injury) type i in the baseline simulation
$I_{Treatment,i}$	severity of (injury) type i in the treatment simulation
P_{CR}	crash rate
P_{K}	probability of being killed in a crash
P_{KSI}	probability of being killed or severely injured in a crash
P_{VR}	victim rate
S	safety performance
S_{i}	safety performance of the injury severity, i
$d_{Cyclist}$	distance of a cyclist to a reference point (position or another vehicle)
d_{DLC}	distance to the lane
d_{Rel}	relative distance between two objects
d_{VUT}	distance of the VuT to a reference point (position or another vehicle)
$f_{Baseline,i}$	occurrence frequency of a scenario with injury level i in the baseline
$f_{Treatment,i}$	occurrence frequency of a scenario with injury level i in the treatment
m	mass
n_{coll}	number of collisions either in the baseline or treatment simulation
n_{vict}	number of victims either in the baseline or treatment simulation
N_{sim}	number of simulations either in the baseline or treatment simulation
t	time
$t_{collision}$	time of the collision
t_{THW}	time headway
t_{TLC}	time to line crossing
t_{TTC}	time to collision
Δt	time step
x	longitudinal position
y	lateral position
v	velocity

v_{Rel}	relative velocity between two objects
v_{VUT}	velocity of the vehicle under test

4.2 Abbreviations

AIS	abbreviated injury scale
ADAS	advanced driver assistance system
AEB	autonomous emergency braking
COG	centre of gravity
CSV	comma-separated values
CVNB	car-to-vulnerable road user near-side bicycle
DLC	distance to line crossing
DP	data point
DS	data series
EDR	event data recorder
EES	energy equivalent speed
FCW	forward collision warning
FE	finite element
FoV	field of view
FOT	field operational test
HIL	hardware in the loop
I2V	infrastructure to vehicle
IRF	injury risk function
KSI	killed or severely injured
MAIS	maximum abbreviated injury scale
NCAP	new car assessment program
ND	normal driving (not safety critical)
NDS	naturalistic driving study
PD	probability distribution
PET	post encroachment time
THW	time headway
TLC	time to line crossing
TTC	time to collision

V2X vehicle to x (vehicle, pedestrian, cyclist and/or infrastructure) communication

VR victim rate

VRU vulnerable road user

V&V validation and verification

VuT vehicle under test

V2V vehicle to vehicle

XML extensible markup language

5 Overview: A general description of the process for prospective safety performance assessment of pre-crash technology by virtual simulation

5.1 General approach and structure

To estimate the performance of technologies designed to avoid or mitigate crashes, the analysis of a high number of scenarios is needed. The general process for prospective safety performance assessment of pre-crash technology by virtual simulation is described in Figure 1 and builds up on ISO/TR 21934-1.

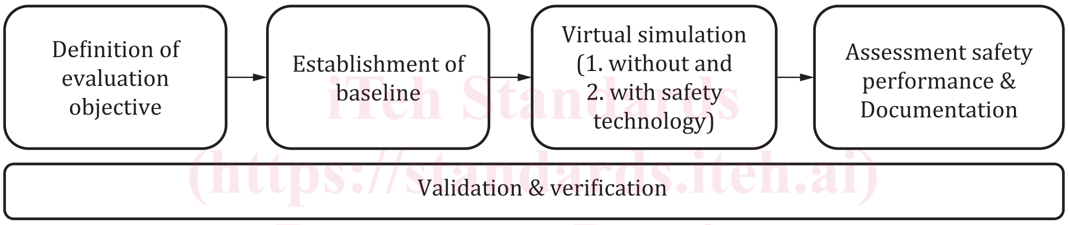

Figure 1 — Overview of the prospective assessment of traffic safety process for vehicle-integrated technology by means of virtual simulation

The process does not provide any development guidelines or assessment results in terms of functional safety (the ISO 26262 series) or safety of the intended functionality (ISO 21448). These topics are covered by other ISO documents. Furthermore, no recommendations are given with respect to the usage of certain input data sources or simulation tools. No methodology advises are given for the scaling up and projection of the simulation results which is often conducted in conjunction with this type of assessment.

5.2 Input data

Input data are required in all parts of the prospective safety performance assessment by simulation. An overview of the information type that is required for the simulation models and process steps and their relevance is given in Table 1. Information about possible data sources is given in ISO/TR 21934-1. The technical format and the type of the input, as well as the definition of minimum required information is crucial for safety performance assessments.