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Road vehicles — Traffic accident analysis — —

Part 4: Compilation of methodologies for assessment of vehicle safety system effectiveness

Véhicules routiers — Analyse des accidents de la circulation — —

Partie 4: Compilation dedes méthodologies pour l'évaluation de l'efficacité des systèmes de sécurité des véhicules

DTR stage

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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 12353 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

Many methodologies are used to analyse the effectiveness of various vehicle safety systems. Most methods are retrospective, have different applicability, advantages and limitations, and are often chosen depending on the structure and content of the data available. More recently, prospective methods have been presented and used.

The aim of this document is to compile commonly used methods for assessing the effectiveness of vehicle safety systems. The document covers assessment methods for active, passive and integrated safety systems including crash avoidance systems. The effectiveness in this context refers to the capability of a safety system or feature to avoid or mitigate injuries, fatalities or crashes.

The document provides a general overview of commonly used terms for the assessment methodologies, including exposure, risk, odds, effectiveness, benefit and safety performance.

Six methodologies, both prospective and retrospective, are described in the document. Each method is summarized in terms of its applicability, advantages and limitations. The methodology is described together with necessary input data and the resulting output data. Conclusions are given in terms of accuracy, sensitivity and validation for each method.

An overview of the applicability of prospective and retrospective assessment methods is also included (see Annex AAnnex A).).

The methods included in this document were considered to be in use and valid for this compilation by the time of development. If needed and requested, this document can be expanded with additional methods in a later revision.

Road vehicles — Traffic accident analysis — —

Part 4: Compilation of methodologies for assessment of vehicle safety system effectiveness

1 Scope

This document compiles common methods for assessing the effectiveness of vehicle safety systems. This covers active, passive and integrated safety systems including crash avoidance systems.

Effectiveness in this context refers to the capability of a safety system or feature to avoid or mitigate injuries, fatalities or crashes.

The document covers both prospective and retrospective methodologies. Applicability, advantages, limitations, accuracy and sensitivity are described for each method. Necessary input and output data and format are also presented.

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 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 in ISO 12353-1 and the following apply.

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

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

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

3.1
mitigate
reduce the consequences of a hazardous event

Note 1 to entry: In the context of this document, the consequences are injuries, fatalities or crash severity.

3.2
injury risk
IR
probability of occurrence of a personal injury at a specific level

Note 1 to entry: Injury level is often expressed with the abbreviated injury scale (AIS).

3.3
relative risk
risk ratio
ratio of risk of an event in one group versus the risk of the event in the other group

EXAMPLE An exposed group versus a non-exposed group.

3.4
odds
probability that the event occurs divided by the probability that the event does not occur

3.5
odds ratio
probability of an event occurring in one group versus the probability of the event occurring in the other group

3.6
eccentricity
distance between the impact force vector of the centres of gravity of the two vehicles in an eccentric impact

4 Symbols and abbreviated terms

A	number of accident situations sensitive to the system
AEB	autonomous emergency brake
ADAS	advanced driver assistance system
B	benefit
C	crash-momentum index
E	effectiveness
F	field of effect
IR	injury risk
N	number of (all) accident situations
n	number of crashes (of a certain type)
P	crash rate
PDO	property damage only
Q	penetration factor
R	relative risk (risk ratio)
S	safety performance
ΔV	change of velocity (delta-v)
X	exposure

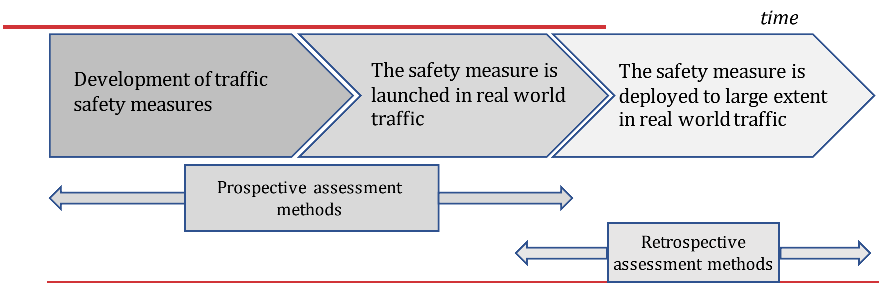
5 Overview of assessment methodologies

5.1 Prospective and retrospective methods

Assessments are calculations of performance that tell the value of a subject in comparison to an aim or objective. This document describes commonly used assessment methodologies for traffic safety measures in vehicles in the complete driver-vehicle-traffic system (i.e. when the measure is deployed in the real-world traffic with the wide-ranging distribution of environments and traffic participants).

The two main types of assessments are studies performed before (prospectively) or after (retrospectively) the introduction of a safety measure, see Figure 1~~Figure 1.~~. The headings of the clauses in this document ~~indicates~~indicate whether the assessment method described is prospective or retrospective.

Methodologies to categorize traffic safety performance assessments use tools (e.g. virtual simulation, accident database analysis) and/or input data (e.g. crash data, naturalistic driving data). Tools and input data are discussed for each method in this document. Some applications of prospective and retrospective methods are given in Annex A~~Annex A.~~.



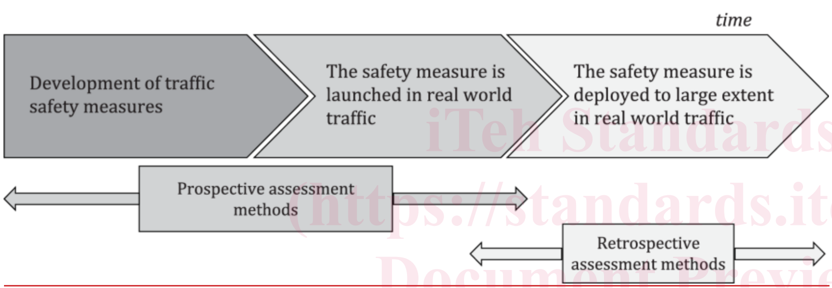


Figure 1 — Illustration of prospective and retrospective assessment methods

5.2 Exposure

The traditional definition of exposure is of being in a place or situation where there is no protection from something harmful or unpleasant. According to ISO 26262-1, exposure is defined under functional safety as the state of being in an operational situation that can be hazardous, which can occur at any point in a vehicle's lifetime (a combination of an operational situation and a potential source of ~~).~~harm). A similar interpretation is given in ISO 21448, which refers to the ISO 26262 series. In these documents, exposure is a factor for potential risk calculation that describes the (expected) frequency of occurrences of situations of interest. For prospective accident research, a similar approach is taken in case the frequency of scenarios is relevant for the calculation of the risk of accident.

For retrospective traffic accident research, the perspective is different, since the focus is on the calculation of accident rates for different groups. These groups can be defined by other parameters, such as technologies, vehicle types, road types and driver types. A simple comparison of the number of accidents can be misleading in the analysed data set. Therefore, a rate is calculated to correct the comparison for the different representation of the groups. In Reference [3~~Evans[3]~~] the problem is illustrated ~~the problem~~ by asking which sex is more likely to be involved in accidents. Although there are copious data available on the number of accidents in which male and female drivers are involved, this question remains difficult to solve, since it requires comparison of the number of accidents per unit of exposure for each group. Typical units for exposure are travelled distance or time, traffic density and/or crash severity.

Thus, in retrospective accident analysis, exposure is defined according to ISO 12353-1 as a parameter describing the dose or amount of some physically measurable parameter(s) that are related to an accident or injury or both.

5.3 Risk

According to ISO 26262-1, risk is the combination of the probability of occurrence of harm and the severity of that harm.

In this document, risk is the probability of occurrence of an accident with a specific severity (due to the application of a safety system).

As for the risk of personal injury, injury risk (IR) is the probability of occurrence of a personal injury at a specific level.

The severity of an accident is estimated by the type of injuries and the extent of affected people, for example:

— property damage only (PDO);

— minor, major or lethal injuries;

— one or several persons, objects.

The probability of occurrence of harm depends on the exposure to the hazard, the occurrence of relevant situations and the possibility to avoid or limit harm by external factors:

— how often or how much time is spent with the hazardous object;

— relevant statistical, historical or reference information;

— skillset and awareness of user, experience, lead-time to harm.

5.4 Odds

Odds is defined as the probability that the event will occur divided by the probability that the event will not occur.

The odds ratio is the ratio of the odds of an event in one group versus the odds of the event in the other group.

NOTE See also Reference [4 [4].].

5.5 Field of effect

The field of effect, *F*, defines a specific subset within a superset of considered accident situations. The superset of traffic situations contains all occurrences recorded in a particular region. The accident situations in the field of effect are specified by common characteristics. These can be, for instance, accident causes, accidents scenarios, involved participants and other concomitant circumstances.

In practice, the field of effect is the proportion of all accident situations in which a specific safety system can have a positive effect. The safety system is designed to become active in these situations in order to avoid or mitigate the accident. Thus, the field of effect describes all accident situations that are addressed by the safety system.

The field of effect is calculated using Formula (1)Formula (1)::

$$F = \frac{A}{N} \times \frac{A}{N} \times 100 \quad (1)$$

where

F	is the field of effect, expressed in per cent;
A	is the number of accident situations sensitive to the system;
N	is the number of all accident situations.

EXAMPLE The field of effect of an autonomous emergency brake (AEB) system comprises all run-up accidents between cars. About 6 % of all injury accidents in Germany are car-to-car run-up accidents that can be addressed by AEB.

5.6 Effectiveness rate

The effectiveness rate defines the proportion of accident situations in the field of effect that are positively affected by the regarded safety system. It describes how well the safety system performs within its field of effect.

The effectiveness rate of the safety system depends on how well the system addresses all possible accident situations within the defined field of effect. It also relies on a reliable and functioning system performance. Ideally, all system-specific accident situations are avoided or at least mitigated by the safety system.

The effectiveness rate is calculated by Formula (2)Formula (2)::

$$E_{Rate} = \frac{A_{Reduction}}{A} = \frac{A_{Reduction}}{A} \times 100 \quad (2)$$

where

E_{Rate}	is the effectiveness rate, expressed in per cent;
$A_{Reduction}$	is the number of avoided or mitigated accidents that are sensitive to the system;
A	is the total number of accidents sensitive to the system.

EXAMPLE The effectiveness rate of an AEB system specifies the part of all car-to-car run-up accidents that are avoided or mitigated by AEB. The AEB effectiveness rate amounts to approximately 90 %.

5.7 Potential effectiveness

The potential effectiveness defines the maximal proportion of all accident situations that are positively affected by the safety system. It describes the overall benefit of a safety system if all vehicles in the field were equipped with such a system.

The potential effectiveness is calculated by Formula (3)Formula (3)::

$$E_{Pot} = \frac{A_{Reduction}}{N} \times = \frac{A_{Reduction}}{N} \times 100 \quad (3)$$

where

E_{Pot}	is the potential effectiveness, expressed in per cent;
$A_{Reduction}$	is the number of avoided or mitigated accidents that are sensitive to the system;
N	is the total number of all accidents.

If the field of effect and the effectiveness rate are known, the potential effectiveness can be calculated as in Formula (4)Formula (4):.

$$E_{Pot} = \frac{F \cdot E_{Rate}}{100} = \frac{F \cdot E_{Rate}}{100} \qquad (4)$$

where

E_{Pot}	is the potential effectiveness, expressed in per cent;
F	is the field of effect, expressed in per cent;
E_{Rate}	is the effectiveness rate, expressed in per cent.

EXAMPLE 1 The potential effectiveness of an AEB system specifies the part of all accidents that are avoided or mitigated by AEB. If the field of effect is 6 % and the effectiveness rate is 90 %, the potential effectiveness is 5,4 %.

Figure 2Figure 2 shows an illustration of the exposure and effectiveness definitions.