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Road vehicles — Advanced automatic collision notification (AACN) systems — Methodology for creating and validating algorithms for injury level prediction

Véhicules routiers — Systèmes intelligents de notification automatique de collision — Méthodologie pour créer et valider les algorithmes de prédiction du niveau de blessure

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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*.

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Introduction

This document provides guidance on advanced automatic collision notification (AACN) algorithms for injury level prediction and related parameters. Guidance on the evaluation of such AACN algorithms is also presented. This document does not establish a particular AACN injury level prediction algorithm or impose a specific input data set.

This document contributes to an appropriate implementation, overall, saving lives. Different parties (as listed below) will benefit from applying this document.

Benefits for implementors (e.g. OEMs, countries) listed below for implementor groups respectively:

— implementors currently not having an AACN algorithm: this document helps to efficiently develop and evaluate one, facilitating more rapid introduction;

— implementors having AACN algorithm already in a region: implementors can use this document to demonstrate appropriateness;

— implementors having an AACN algorithm and wanting to enter new market: this document helps to ensure and demonstrate appropriateness for new market.

Benefits for first respondents, doctors and paramedics:

— advance estimation of expected injury severities in the crash scene;

— unifying advance estimation increases the possibility of using algorithms providing similar estimations of injury severity;

— reduced time to start medical treatment and improved triage for injured road users involved in a crash.

Benefits for society:

— end users are all road traffic participants involved in a traffic accident. In a collision, car occupants and/or vulnerable road users can have a better chance to mitigate or survive injuries when there is an AACN injury level prediction algorithm to facilitate rapid response by dispatching appropriate emergency services.

Road vehicles — Advanced automatic collision notification (AACN) systems — Methodology for creating and validating algorithms for injury level prediction

1 Scope

This document outlines methodologies for creating and evaluating AACN algorithms, using suitable parameters, to predict the level of injury sustained by road users in a collision.

The injury prediction is used to facilitate emergency response after a collision occurs.

The methodology is based on onboard vehicle data and occupant-related information and applies to vehicle occupants and vulnerable road users.

This document is applicable to road vehicles having provisions for measuring and communicating crash related data.

This document provides neither a particular AACN injury level prediction algorithm, nor information on how to use the estimated probability of injury to decide on further suitable actions (rescue, medical, etc.).

Data format for sending vehicle information and communication protocol between the vehicle and the public service answering point (PSAP) is outside the scope of this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
advanced automatic collision notification system
AACN system
system that carries out automatic notification of traffic accidents, providing information measured by the vehicle aiming to predict the level of injury sustained by road users

Note 1 to entry: Additional information (not measured by the vehicle) available just after the *crash* (3.12) can be used for the prediction.

3.2
event data recorder
EDR
device or function in a vehicle that records the vehicle's dynamic, time-series data during the time period just prior to a crash event (e.g. vehicle speed versus time) or during a crash event (e.g. Δv versus time), intended for retrieval after the crash event

Note 1 to entry: For the purposes of this definition, the event data do not include audio and video data.

Note 2 to entry: At the time of developing this document, EDR data do not include audio or video information.

[SOURCE: Reference [5], modified — Note 1 to entry was originally part of the definition, Note 2 to entry was added.]

3.3
injury risk curve
curve giving the probability, for a defined population and for a given input, to sustain a specified severity of injury

[SOURCE: ISO/TS 18506:2014, 2.1]

3.4
retrospective traffic accident data
sets of historical traffic accident data grouped by analysis category

3.5
triage
rapid process of sorting people depending on their need for immediate medical treatment (as is usually done in emergencies)

Note 1 to entry: See also 7.2 for use of triage and related definitions in the context of AACN according to this document.

3.6
under-triage
UT
state in which a system has assessed a person as suffering from a minor injury or no injury, when the person has suffered a severe or fatal injury

Note 1 to entry: See also 7.2 for use of *triage* (3.5) and related definitions in the context of AACN according to this document.

3.7
under-triage rate
UTR
value obtained by dividing the number of severe or fatal injuries assessed as minor or no injuries by the number of cases that actually suffered a severe or fatal injury

Note 1 to entry: See also 7.2 for use of *triage* (3.5) and related definitions in the context of AACN according to this document.

3.8
over-triage
OT
state in which a system has assessed a person as suffering from a severe or fatal injury, when the person has actually suffered a minor injury or no injury

Note 1 to entry: See also 7.2 for use of *triage* (3.5) and related definitions in the context of AACN according to this document.

3.9
over-triage rate
OTR
value obtained by dividing the number of minor or no injuries assessed as severe or fatal injuries by the number of cases that actually suffered a minor or no injury

Note 1 to entry: See also 7.2 for use of *triage* (3.5) and related definitions in the context of AACN according to this document.

3.10
algorithm
set of rules or calculations applied to test data that generate an interpretable or reportable result

[SOURCE: ISO 21474-1:2020, 3.2]

3.11
injury level prediction
injury severity prediction
prediction of the level of injuries from a given set of input parameters with certain values of the probability as threshold

3.12
crash
situation in which the subject vehicle has any contact with at least one other conflict partner either on or off the trafficway, either moving or stationary (fixed or non-fixed), that is observable or in which kinetic energy is measurably transferred or dissipated

Note 1 to entry: This excludes roadway features meant to be driven over such as speed bumps and low roadside barriers (curbs, medians, etc.) within the ground clearance limitations of the vehicle.

Note 2 to entry: A crash can also be a single-vehicle conflict that includes at least one of the following conditions: vehicle rollover, airbag deployment, injury, more than 90° degrees of horizontal vehicle rotation, or all four tires leaving the trafficway.

Note 3 to entry: In this document, the terms crash and collision are used interchangeably.

[SOURCE: ISO/TR 21974-1:2018, 3.4, modified — Note 3 to entry has been added.]

3.13
eCall
system to provide notification and relevant coordinate information to public-safety answering points, by means of wireless communications, that there has been an incident that requires a response from the emergency services

[SOURCE: ISO 24978:2009, 4.2]

3.14
vulnerable road user
VRU
non-protected road user such as motorcyclists, cyclists, pedestrians and persons with disabilities or reduced mobility and orientation

[SOURCE: ISO/TR 4804:2020, 3.68]

4 AACN injury severity prediction overview

This clause provides an overview of injury severity prediction in AACN systems for motor vehicle collisions.

Figure 1 shows general factors related to impact severity and injury outcome in the pre-crash, crash and post-crash phases. The factors are divided into those related to impact severity and those related to injury mechanisms and outcome. Several factors have related input parameters that can be used for an AACN system and are also referenced in this document, see for example Table 1 and Table 2.

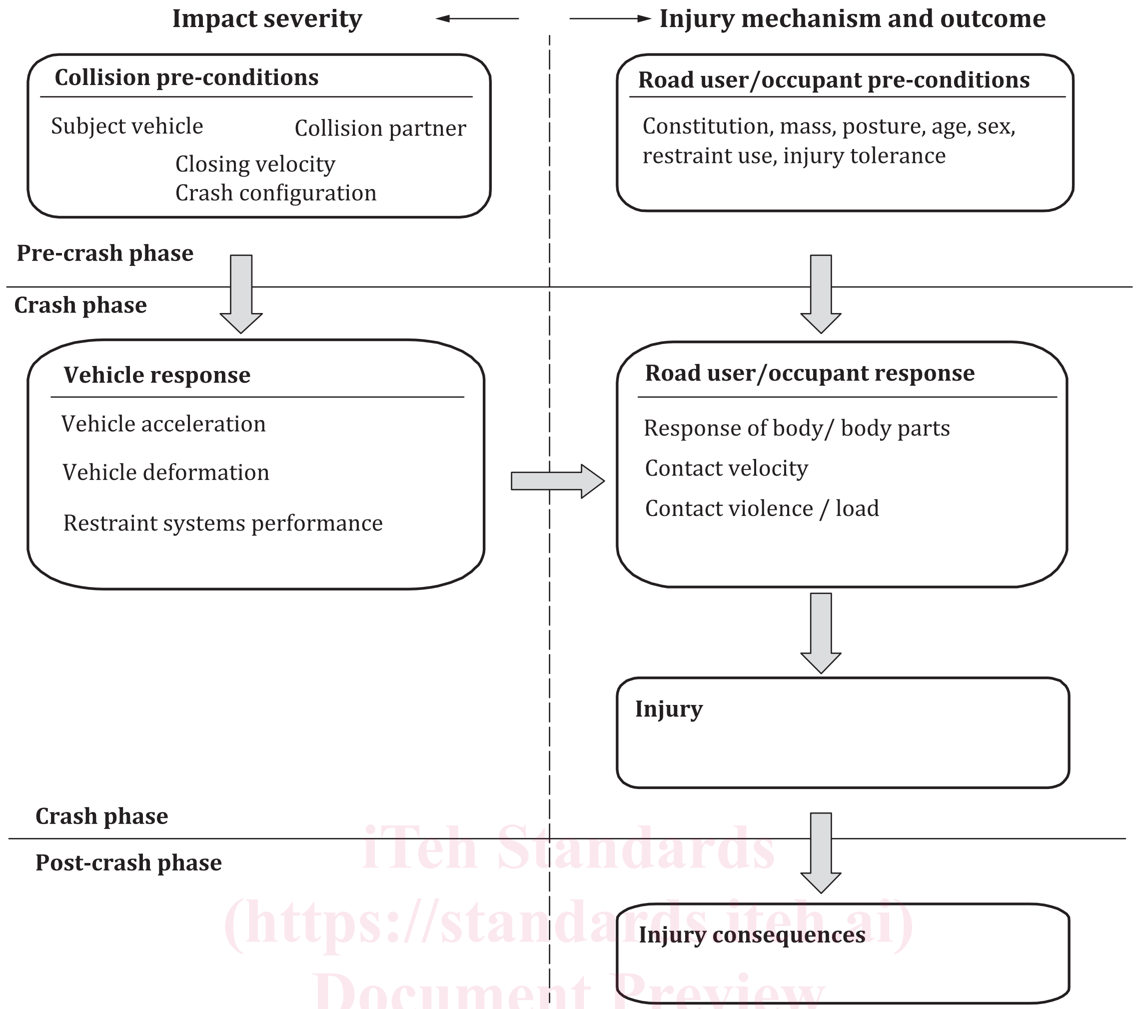

Figure 1 — Factors related to impact severity and injury outcome

Previous publications, as described in Annex A, document a variety of injury severity prediction models currently in use around the globe. These models all seek to improve outcomes for people involved in motor vehicle collisions by supporting the rapid deployment of appropriate emergency response. Generally, models are based on retrospective traffic accident data, including characteristics of the crash, involved vehicles, and occupant outcomes. Statistical analysis methods are used to derive a relationship between accident factors and the degree of injury sustained. This relationship is then used to predict the degree of injury sustained by a person in a specific accident near real time, to facilitate proper triage.

While the objective and general development approaches of injury severity prediction models are similar, the literature reveals differences in specific model formulations. Many of these differences are traceable to the underlying retrospective datasets used in model fitting. For example, one key variable in predicting occupant injury outcomes is the velocity of involved vehicles before and during a collision. Retrospective crash data sets vary in how velocities are captured, some leveraging vehicle-based measures of pre-crash speed or crash change in velocity, Δv, others using police-reported speed estimates, and still others relying on posted speed limits.

Differences in input accuracy and granularity can affect the significance of factors in predicting injury outcomes.

Additional differences in models are due to contextual differences where models are implemented. In some cases, emergency resources are centrally dispatched by a small number of specialized resources. Training users to interpret and act on model outputs in such environments is easier than in distributed contexts with many dispatchers managing different types of constrained emergency response resources.

Based on current knowledge, this document describes input data and modelling approaches used in injury severity prediction. It also describes methods for validating model performance and highlights potential pitfalls.

5 Vehicle and road user data for injury prediction application

5.1 Introduction

To predict injury risk, algorithms are generally developed using historic collision data. In order to predict injury at the time of collision, there is a primary requirement for information automatically collected by the vehicle to be transmitted in near-real time at the time of collision. This information can be supported by parameters collected shortly after the collision, for example via telecommunications link to the vehicle and its occupants, or other sources.

This clause explores current and possible future parameters available from historic collision data, near-real time vehicle sensor data and other data sources. Algorithms can be created from historic collision data using vehicle and occupant related parameters, and therefore 5.2 and 5.3 are separated by vehicle-related and occupant-related data parameters.

Based on a review (see NOTE 1 in this subclause) of current EDR regulations, AACN literature, eCall transmission possibilities and vehicle parameters available in accident databases (national level and in-depth level) three categories of relevant vehicle-related input parameters can be defined:

— A: considered available and widely used in AACN applications at the time of publication of this document;

— B: considered potentially available and useful at the time of publication of this document;

— C: considered potentially available and useful in the future at the time of publication of this document.

NOTE 1 See Annex A, Table A.2: Studies of existing AACN algorithms which use some parameters; overview of EDR regulation (US, China, UN ECE & EU); eCall possibilities; status of accidents databases content.

NOTE 2 In this clause, only the vehicle parameters that can be automatically transmitted by the vehicle itself after the crash are included. Information that can be obtained by a discussion between PSAP member and vehicle occupant is not included.

NOTE 3 “Available” means that the information is available in the vehicle (EDR or other data recording and storage systems) at the time of the accident, and that the over the air transmission is feasible. In order to construct an algorithm, historic collision data is most commonly used. Therefore, available parameters must also be available in the historic collision data used to create the algorithms.

NOTE 4 "Useful” means that those parameters are relevant to estimate occupant injury severity based on previous work conducted using accident databases.

For any collision, the type of impact sustained by the vehicle is relevant for injury severity prediction. A list of relevant inputs for AACN injury level prediction algorithms can be split by the following main impact types:

— frontal impact;

— side impact;

— rear impact;

— roll over.

NOTE 5 "Impact" is used according to the definition in ISO 6813:1998, 3.4.

NOTE 6 An alternative categorization can be done according to the direction of principal force (PDOF), according to the definition in ISO 6813:1998, 3.4.2.2.

In case of multiple impact detection, parameters corresponding to each impact should be considered. The implication of multiple impacts occurring even without further impact severity information should be considered for the injury severity prediction.

5.2 Vehicle-related input parameters

Table 1 shows the key vehicle-related input parameters for each type of detected impact, separated into the three categories, for usage or future usage in AACN algorithms.

Table 1 — Example vehicle-related input parameters relevant to AACN

	Frontal impact detection	Rear impact detection	Side impact detection	Roll over detection
Category A	Maximum Δv – longitudinal (+/-)		Maximum Δv – lateral	Maximum roll rate
	Maximum Δv – resultant (total)			-
	Collision direction – front	Collision direction – rear	Collision direction – driver side – non-driver side	Collision direction – roll over
	Restraint system (e.g. seat belt) status			
Category B	Time to maximum Δv – longitudinal		Time to maximum Δv - lateral	Time to maximum roll rate
	Maximum Δv – lateral		Maximum Δv – longitudinal	Maximum Δv – lateral
	Vehicle speed			
	Relative velocity			
	Airbag or seatbelt pretensioner deployment			
	Airbag and seatbelt pretensioner deployment times			
	–			maximum roll angle (number of rolls)
	Multiple events collision			
Category C	Intrusion magnitude			
	Maximum deformation location			

5.3 Vehicle occupant-related input parameters

Table 2 shows a range of vehicle occupant-related input parameters, for usage or future usage in AACN algorithms. Some parameters, such as occupant age, are already widely used in existing AACN algorithms even though the age information may not be available in real-time. Methods such as telecommunications link with the vehicle are currently used to assist the emergency services in obtaining this information remotely. In future it is expected that there will be a greater ability for vehicles to utilize in-vehicle sensors to obtain occupant characteristic information, which could be leveraged by future AACN systems.

Table 2 — Example vehicle occupant-related input parameters relevant to AACN

	Input parameters
Category A	–
Category B	Age
	Sex
	Seat occupancy
	Restraint status of each occupant (including in child restraints and adults belted)

[a] Occupant height and weight information can be available using personalised keys or by inputting the values in advance as driver information, or by using the seat sensors to detect weight and seat slide position.

Table 2 *(continued)*

	Input parameters
Category C	Vital signs from biometric sensors (e.g. heart rate, respiratory rate)
	Pre-existing health conditions (comorbidities)
	Occupant characterization [a] (child/adult; size, height & weight)
	Occupant seat position (track position captured by in-vehicle sensors)
	Atypical occupant seating position (out-position, lying down, rear-facing, etc.), e.g. by in-vehicle radar
	Information available from occupant monitoring technologies (such as camera, radar, infrared), e.g. occupant consciousness level or pupil monitoring.

[a] Occupant height and weight information can be available using personalised keys or by inputting the values in advance as driver information, or by using the seat sensors to detect weight and seat slide position.

5.4 Vulnerable road user data

Some input parameters considered useful for estimating injury risk for vulnerable road users (VRUs) are listed in Table 3. At the time of publication of this document there are no known implemented AACN algorithms for VRUs. This is due to the challenge presented in reliably detecting VRU collisions using vehicle sensors.

Table 3 includes parameters which could feasibly give an indication of VRU injury severity and how they may be detected at the time of a collision, now and in future. Table 3 does not contain an exhaustive list and as instrumentation develops there is likely to be an increasing number of possibilities for data collection during collisions involving a range of road users.

Table 3 — Example VRU-related input parameters relevant to AACN

VRU-related input parameters	Potential detection mechanism
Impact velocity (v_0) for striking vehicle	Travel speed from event data recorder (EDR)
Collision direction for striking vehicle Impact location of VRU on striking vehicle	Systems sensitive to collisions in the direction of striking vehicle travel Inferred from activation of VRU protection system (e.g. active bonnet, VRU airbags) Image-based detection technologies Passenger cars: parking cameras/sensors Commercial vehicles and buses: Cameras/sensors to monitor blind spot areas
Secondary impact location of VRU on the ground	Image-based detection technologies Passenger cars: parking cameras/sensors Commercial vehicles and buses: Cameras/sensors to monitor blind spot areas
Type of VRU struck (e.g. pedestrian, cyclist, eScooter, other)	Classification based on currently available VRU detection systems
Presence of VRU protection system (e.g. active bonnet, VRU airbags) on striking vehicle	Restraint control module (RCM) VRU control module VRU AEB
Multiple collisions	System capable of detecting two or more impacted VRUs Sequential impact: e.g. loss of control Detection via forward collision warning systems (image-based or otherwise)
VRU trajectory	Image-based (or other sensor-based) detection
VRU characterization (child/adult; size and weight)	Image-based (or other sensor-based) detection
VRU age	Image-based (or other sensor-based) detection

Table 3 *(continued)*

VRU-related input parameters	Potential detection mechanism
VRU sex	Image-based (or other sensor-based) detection
Personal safety devices (e.g. helmet use, type, status, neck brace)	Image-based (or other sensor-based) detection
Pre-impact movement and stance (including gait if relevant)	Image-based (or other sensor-based) detection
Other physical attributes (e.g. posture, personal mobility systems)	Image-based (or other sensor-based) detection
Heart rate, breathing rate and other biometric characteristics	Biometric sensors (e.g. via personal device)

6 Injury prediction algorithm development

6.1 General

This clause provides general information regarding the use of retrospective traffic accident data (from accident databases) in the development of injury risk curve(s) in the AACN context. Considerations regarding the limitations of the data, along with an example is provided.

NOTE See also ISO/TS 18506.

6.2 Applicability of retrospective data for AACN use

Retrospective traffic accident data are limited to the characteristics of the system that generated that data. A partial list of considerations follows:

— Occupant demographics: some populations can skew older or have high BMIs, which in turn can impact the outcomes in the available data.

— Vehicle characteristics: regions that have greater dispersion of vehicle mass can also have greater dispersion of Δv, such as where a significant volume of larger passenger vehicles like full size trucks and SUVs share the road with smaller cars.

— Emergency response systems: EMS response can vary between and within countries. For example, in a lightly congested but well-resourced suburban location, EMS response and access to hospitals can be significantly different than in a crowded urban area or sparsely populated rural area, which can contribute to differing outcomes even if the same crash dynamics are involved.

— Road systems and quality: as with EMS response, differing road systems may impact response times and contribute to differing outcomes even if the same crash dynamics are involved.

When using retrospective data sources for the purposes of predicting injury severity, these regional differences that manifest in the outcome data need to be accounted for. Particular attention should be paid to the sources of the crash data used to develop an injury prediction model. As time progresses and the vehicle population shifts toward newer vehicles equipped with newer active and passive safety systems, it is expected that models used to predict injury will need to change as well. This will require re-evaluating model performance over time and may periodically require recalibrating model parameters or developing a new model altogether.

NOTE See also Clause 9 regarding spatial and temporal validity.

6.3 Modelling methods

6.3.1 Introduction

There are many possible methods to choose from when developing an injury prediction algorithm. Since the fundamental problem is to classify a crash outcome into various severity categories, commonly used classification methods can be employed. These include (but are not limited to): logistic regression, k-nearest