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Cestna infrastruktura - Avtomatizirane interakcije vozil - Referenčni okvir, različica 1

Road infrastructure - Automated vehicle interactions - Reference Framework Release 1

Straßeninfrastruktur - Bezugsrahmen für die Interaktion automatisierter Fahrzeuge

Interactions Infrastructure routière - Véhicule automatisé : Cadre de référence Version 1

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Road infrastructure - Automated vehicle interactions - Reference Framework Release 1

Interactions Infrastructures routières - Véhicules automatisés - Cadre de référence

Straßeninfrastruktur - Bezugsrahmen für die Interaktion automatisierter Fahrzeuge

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European foreword

This document (CEN/TR 17828:2022) has been prepared by Technical Committee CEN/TC 226 “Road equipment”, the secretariat of which is held by AFNOR.

This document provides a pre-standardization study for the road infrastructure – automated vehicle interactions which will be used by WG12 as a reference framework for the development of other pre-standardization studies.

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Introduction

A shared general vision between the main stakeholders which are involved in the development and deployment of automated vehicles is that their complexity requires a constant effort to converge toward safe, interoperable solutions.

This complexity is related to the considered mobility environment, in terms of road topography, traffic and weather conditions, human behaviour, vehicle diversity, etc.

This led these main stakeholders to think that it is necessary, in a certain number of situations, to provide some forms of cooperation between the roadside infrastructure (road equipment) and automated vehicles.

Such necessity is reinforced through the fact that the deployment of automated vehicles will be progressive, leading to a heterogeneous mix of different levels of automated vehicles from not automated in-service vehicles (SAE level 0) to fully automated vehicles (SAE levels 4 &5).

This cooperation will require different forms of interactions between the road equipment and the embedded ADAS of automated vehicles. These interactions should be reliable and secure in such a way to be fault tolerant during the fulfilment of the main functions of the automated vehicle. This latest constraint means that system redundancy will be a key element ensuring the required functional safety of the system.

1 Scope

This document provides the current road equipment suppliers' visions and their associated short term and medium-term priority deployment scenarios. Potential functional/operational standardization issues enabling a safe interaction of road equipment/infrastructure with automated vehicles in a consistent and interoperable way are identified. This is paving the way for a deeper analysis of standardization actions which are necessary for the deployment of priority short-time applications and use cases.

This deeper analysis will be done at the level of each priority application/use case by identifying existing standards to be used, standards gaps/overlaps and new standards to be developed to support this deployment.

The release 1 is focusing on short-term (2022 to 2027) and medium-term deployment. Further releases will update this initial vision according to short term deployment reality.

The objectives of this document are to:

— Support the TC 226 and its WG12 work through the development of a common vision of the roles and responsibilities of a modern, smart road infrastructure in the context of the automated vehicle deployment from SAE level 1 to SAE level 5. The roles and responsibilities of the road infrastructure are related to its level of intelligence provided by functions and data being managed at its level.

— Promote the road equipment suppliers' and partners' visions associated to their short-term and medium- term priorities to European SDOs and the European Union with the goal of having available relevant, consistent standards sets enabling the identified priority deployment scenarios.

NOTE Road equipment/infrastructure includes the physical reality as its digital representation (digital twin). Both need to present a real time consistency.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms, definitions and abbreviated terms apply.

3.1 Terms and definitions

3.1.1
use case
specific situation describing stakeholders' interactions which illustrate the execution of one or several customers' service(s) via support applications

Note 1 to entry: The stakeholders' interactions are represented via standardized exchanges between elements constituting the Intelligent Transport System (ITS).

3.1.2
user
equipped or un-equipped road user such as drivers, vulnerable road users and suppliers which are themselves accessing services provided by a private or public organization

3.1.3
personal ITS-S
ITS-S in a nomadic ITS sub-system in the context of a portable device

3.1.4
traffic scenario
possible behavioural of a use case situation in the form of a sequence of events that affect the mobility and safety with respect to the initial situation

Note 1 to entry: Scenario is defined in terms of the positioning of a User and other road users, environmental situations, the system equipment, and any obstacles and environmental conditions hampering the detectability of the User, the behavioural relations and communication performance of the ITS system. Therefore, the sequence of events includes road user activities, movement of obstacles, and changes in the conditions that affect the VRU safety with respect to the initial situation.

3.1.5
deployment scenarios
main steps to be followed to deploy and manage a functionally and operationally specified system during its whole life cycle, starting with the system installation and commissioning and finishing with its recycling

Note 1 to entry: If the system is a new one, its compatibility with existing legacy systems needs to be considered.

3.1.6
manoeuvres
specific and recognized movements bringing an actor, e.g. vulnerable road user, vehicle or any other form of transport, from one position to another with a given velocity (dynamic)

3.1.7
traffic conflict
situation involving two or more moving users or vehicles approaching each other in such a way that a traffic collision would ensue unless at least one of the users or vehicles performs an emergency manoeuvre

Note 1 to entry: Traffic conflicts are defined by the following parameters:

— traffic conflict point (time and space) where the trajectories intersect,

— time-to-collision, distance-to-collision, post-encroachment time, and angle of conflict.

3.1.8
road
way allowing the passage of vehicles, people and/or animals that is made of none, one or a combination of the following lanes: driving lane, bicycle lane and sidewalk

3.1.9
vehicle
road vehicle designed to legally carry people or cargo on public roads and highways such as busses, cars, trucks, vans, motor homes, and motorcycles

Note 1 to entry: This does not include motor driven vehicles not approved for use of the road, such as forklifts or marine vehicles.

3.1.10
vru
non-motorized road users as well as L class of vehicles

Note 1 to entry: L class of vehicles are defined in Annex I of EU Regulation 168/2013.

3.1.11
vru-s
ensemble of ITS stations interacting with each other to support VRU user cases, e.g. personal ITS-S, vehicle ITS-S, roadside ITS-S or Central ITS-S

3.2 Symbols and abbreviated terms

ACC	Adaptive Cruise Control
ADAS	Advanced Driving Assistance System
AEBS	Advanced Emergency Braking System
CACC	Cooperative Adaptive Cruise Control
CAM	Cooperative Awareness Message
CCAM	Cooperative, Connected Automated Mobility
CDA	Cooperative Driving Automation
CEDR	Conférence Européenne des Directeurs de Routes
CPM	Collaborative Perception Message
CPS	Collaborative Perception Service
C-ITS	Cooperative ITS
CMC	Connected Motorcycle Consortium
C2C-CC	Car to Car Communication Consortium
DENM	Decentralized Environmental Notification Message
DDT	Dynamic Driving Task
FMECA	Failure Mode Effects and Criticality Analysis
GLOSA	Green Light Optimal Speed Advisory
GNSS	Global Navigation Satellite System
ISAD	Infrastructure Support levels for Automated Driving
ITS	Intelligent Transport System
ITS-S	ITS Station
IVI	In Vehicle Information
IVIM	Infrastructure to Vehicle Information Message
LDM	Local Dynamic Map
LTCA	Long Term Certificate Administration
MANTRA	Making full use of Automation for National Road Transport Authorities
MAP	Map
MCO:	Multi Channel Operation
MCM	Manoeuvre Coordination Message

MCS	Manoeuvre Coordination Service
ODD	Operational Design Domain
PAC V2X	Perception Augmented by Cooperation V2X
PCA	Pseudonyms Certificates Administration
POI	Point Of Interest
POTI	Position and Time management
ROI	Return On Investment
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime services
RTCMEM	RTCM Extended Message
RTK	Real Time Kinematic
SAE	Society of Automotive Engineers
SDO	Standards Development Organization
SPaT	Signal Phase and Timing
STF:	Specialist Task Force
TCU	Telematic Control Unit
TTC	Time-To-Collision
TVRA	Threat Vulnerability Risk Analysis
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to X
VAM	VRU Awareness Message
VBS	VRU Awareness Basic Service
VITS-S	Vehicle ITS Station
VRU	Vulnerable Road Users
VRU-S	Vulnerable Road User System

4 Common basic principles

4.1 Intelligent Transport System in CEN TC 226

According to the European Commission ITS Directive (2010/40/EU), Intelligent Transport Systems (ITS) are advanced applications which without embodying intelligence as such aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated and "smarter" use of transport networks.

ITS integrate telecommunications, electronics and information technologies with transport engineering in order to plan, operate, maintain and manage transport systems.

The TC 226 WG12 is focusing on the road interaction- ADAS / Automated vehicles, meaning that the considered ITS is composed of at least two elements: The road infrastructure and the automated vehicle (including its ADAS) which are interacting together.

The inclusion of automated vehicle in ITS leads automatically to the design and development of innovative services as such system elements are not yet deployed. The automated vehicle standardization is already considered in CEN TC 278, ETSI TC ITS and ISO TC 204 which are all focusing on ITS.

It is then the object of this WG12 to work on the identification of these innovative services, their selection and the associated standardization needs in strong liaisons with the on-going ITS standardization work.

4.2 ITS interactions

An ITS may exhibit several types of interactions which are relevant to all TC 226 WGs. These types of interactions are relative of the functional distribution of the information technologies, data and communication means:

The road may be passive, not embodying some information technology. Examples are the horizontal marking or the vertical signs. However, even such a passive road is designed with a lot of human intelligence. In this case, the interactions with automated vehicles' embedded ADAS are mainly achieved by the vehicle itself using some relevant sensors (ADAS: for example, cameras, radars, lidars). In this case, advanced applications will analyse the collected perception data of the vehicle for automatically, safely guiding it.

Mobile objects (e.g. vehicles, Vulnerable Road Users (VRUs), obstacles, etc.) can also be passively perceived by vehicle sensors and then processed by advanced applications for collision avoidance purposes.

The road infrastructure and mobile objects may be equipped with electronic devices, information processing and telecommunication technologies enabling them to interact and cooperate via standard communication protocols and information exchanges (standard message sets).

Several interaction capabilities are existing at the level of automated vehicles (see Figure 1). These capabilities are constituting a de-facto redundancy system which can be used to detect an ITS failure or a cyberattack and then automatically reconfigure the system to maintain its operationality. However, this advantage requires constantly verifying the consistency of existing interactions results which are providing several sources of information (e.g. the consistency between the horizontal marking / vertical signing and the digital twin, or the consistency between the vehicle autonomous perception and received remote perception via C-ITS).

Direct interactions between the road infrastructure and the automated vehicles are made using actuators and sensors which need to respect minimum quality requirements according to the vehicles ADASs which are using the collected data. These autonomous interactions can be disturbed consecutively to their quality degradation, visibility problems (obstacles or bad weather conditions) or absence.

Cooperative ITS (C-ITS) and more generally vehicles' connectivity is achieved via radio telecommunication (local ad-hoc networks (short range) or global networks (long range)) which of course may be not always available.

A local dynamic map should be accurate enough and complete, reflecting the horizontal marking and vertical signing. The vehicles' map matching is also requiring an accurate vehicle positioning system which is not yet available. A positioning system or the associated digital map should be fault tolerant, resilient in case of temporary perception problems.

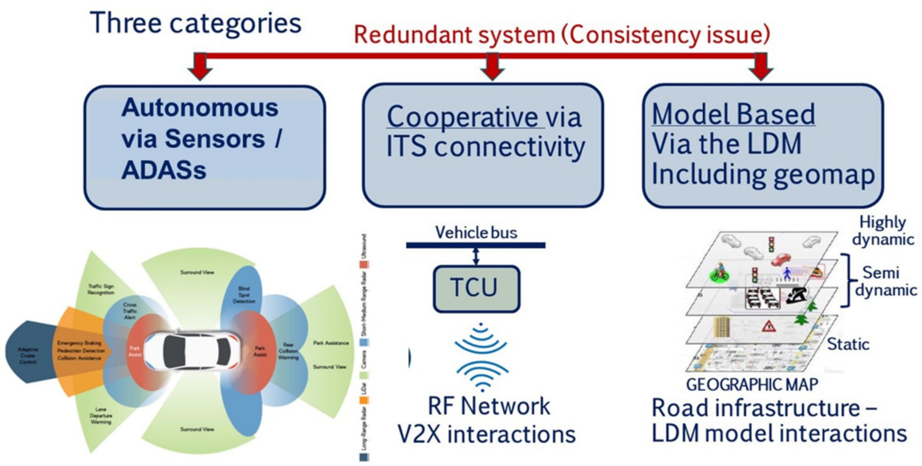

Figure 1 — Three categories of interactions between the automated vehicles and its environment

The consistency of the WG12 approach shall be maintained between Task Groups (TGs) cooperation:

— TG1 needs to consider the perception data fusion between locally collected perception data, remote perception data received from the ITS connectivity and digital data provided by the embedded vehicle Local Dynamic Map (LDM).

— TG4 also needs to maintain the consistency between the Local Digital Map data and the perception data received from local vehicle's sensors.

4.3 Operational Design Domain

Operational Design Domain (ODD) is a description of the specific operating conditions in which the automated driving system is designed to properly operate, including but not limited to roadway types, speed range, environmental conditions (weather, daytime / night-time, etc.), prevailing traffic law and regulations, and other domain constraints [41]. An ODD can be very limited: for instance, a single fixed route on low-speed public streets or private grounds (such as business parks) in temperate weather conditions during daylight hours (Waymo 2017).

The ODD is relevant to all level of automation except for 0 (not applicable) and 5 (unlimited). Any automation use case of level 1 to 4 is usable only in its specific ODD.

4.4 Road infrastructure capabilities

The deployment of automated vehicles needs some evolution of the road infrastructure capabilities, as currently, in-service road infrastructure and equipment are designed only for human driven vehicles. However, such evolution must respect the long-term cohabitation of automated vehicles with human driven vehicles (hybrid environment being discussed here below).

An automated vehicle needs to know if the road infrastructure offers the expected capabilities to stay in automated mode. If it is not the case, SAE level 1 to 3 vehicles may transfer their driving control to the human driver who is still available in the vehicle. However, this transfer decision needs to respect some transition rules ensuring that the driver is ready to take back control of the vehicle. Driving mode transfer is then requiring an anticipation (prediction) of the loss of the road infrastructure capability to support automated vehicles motions.

SAE level 4 and 5 vehicles may not have a human driver inside, however, in such cases they need to be remotely supervised with the objective to be remotely controlled (at least partly) if the road infrastructure no longer offers the expected capabilities.

The Inframix European project proposed an infrastructure categorization model, represented in Figure 2 (ISAD: Infrastructure Support levels for Automated Driving) [33].

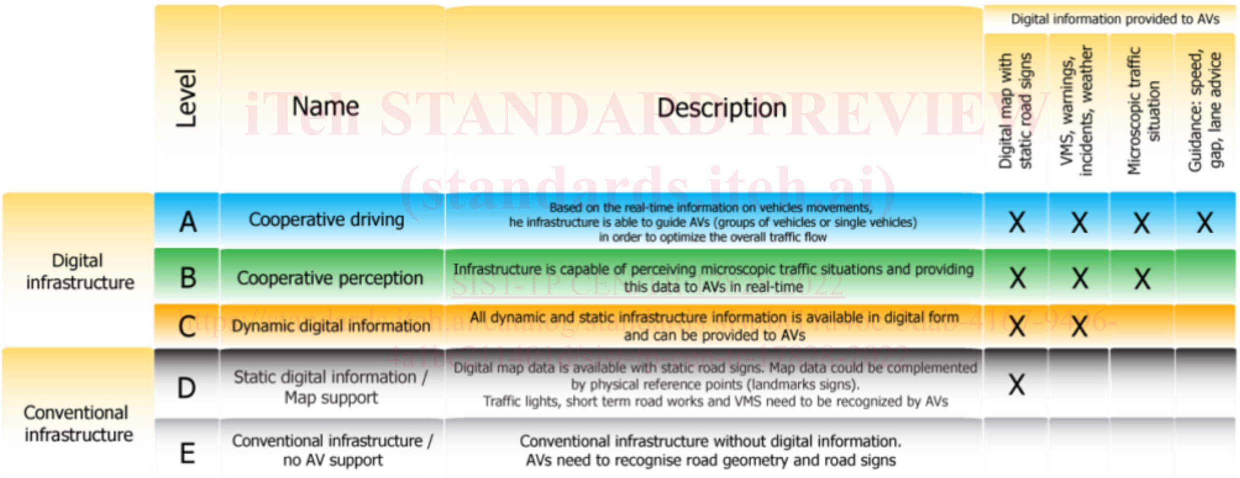

Figure 2 — ISAD levels

4.5 Sustainability principles

The life cycles of vehicles and road infrastructures are covering different long periods of time from their engineering phase to their recycling phase (see Figure 3). These periods of time may be different for the two main system elements (road infrastructure and vehicles).

Interactions between the road infrastructure and the automated vehicles need standard exchange protocols which are not independent of technologies being used. Moreover, preventive, corrective and evolutive maintenance operations need to manage them consistently.

One important operational requirement is the interoperability between interacting road infrastructure elements and automated vehicles elements. This interoperability needs to be maintained during the life cycle of both the road infrastructure and automated vehicles.

This interoperability necessity imposes a specific change management process enabling the secured cohabitation, during determined periods of time, of several versions of standard information exchange protocols without cross disturbances of operational ITS. Different versions need to cohabit together without operational problems.

Such specific change management processes need to be applied in strong concertation between the vehicles' manufacturers and the road operators/managers who have the responsibility to develop together some migration plan including a common and consistent selection of changes to be considered as well as its deployment operation.

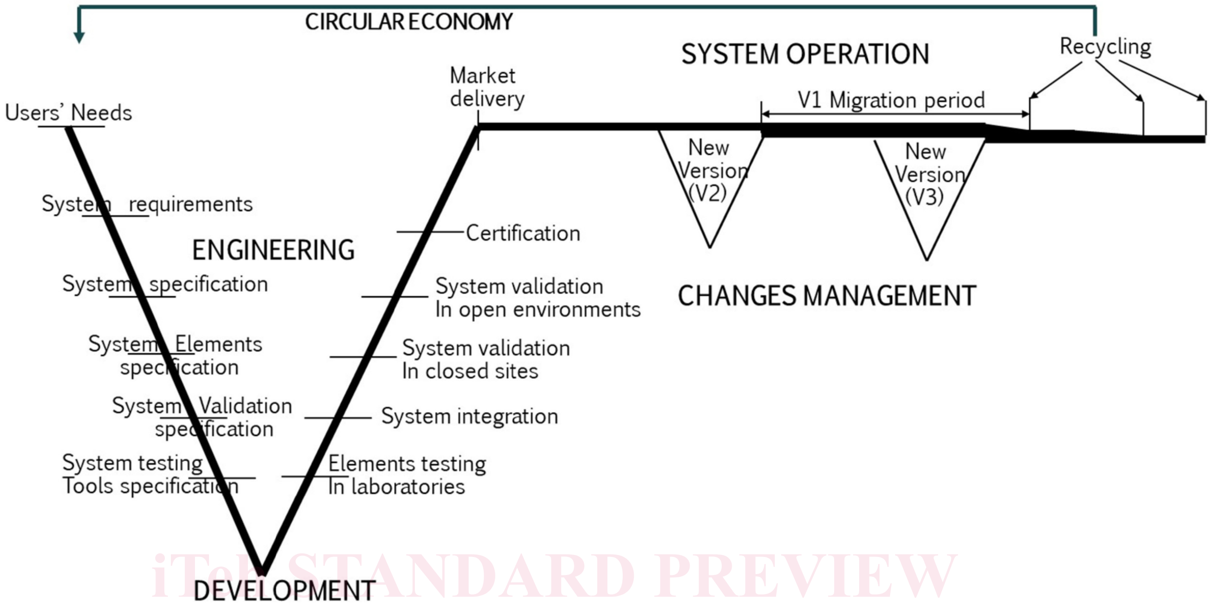

Figure 3 — ITS life cycle

The interoperability requirement needs a continuous cooperation between the main stakeholders of the ITS. This is true at:

— The engineering level for the system and system elements specification. When standards are required, the standards need to be developed/selected in such a way as to enable a full interoperability of the constituted system. Generally, the required standards are regrouped into "profiles" (e.g. "communication profiles", "security profiles", "applications profiles" are constituting what can be called "exchange profiles").

— The engineering level for the system validation including system elements testing, system integration and system validation in diverse environments. Then resulting products can be delivered on the market after a certification/compliance assessment validating their functionality, interoperability and safe operation in targeted environments.

— During the system operation when new versions of the system need to be delivered. In such cases, a change management process is enabling the ITS stakeholders to agree on interoperable evolutions constituting the new version. Some migration plans have then to be proposed to avoid maintaining too many different versions simultaneously.

— The hardware component recycling needs to be considered during their engineering phase.