Rethinking transport
27–30 April 2020

TRA 2020 HELSINKI

Proceedings of 8th Transport Research Arena TRA 2020, April 27-30, 2020, Helsinki, Finland

Infrastructure support for automated driving: Further enhancements on the ISAD classes in Austria

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Abstract

In the emerging sector of Cooperative, Connected and Automated Driving (CCAD), the development of vehicle functions is often in the focus. However, road infrastructure can play a key role in enabling and supporting automated driving. A classification scheme for infrastructure support for automated driving (ISAD) has recently been introduced, which groups the availability of static and dynamic infrastructure information together with communication capabilities into classes. In this paper, this classification is applied to the Austrian motorway network and exemplifies how different classes of infrastructure support can be provided on a road network, ranging from static and dynamic map data to the latest technology for microscopic traffic perception and the integration with the C-ITS deployment. Such an infrastructure classification can be regarded as a tool to systematically define road sections where automated driving functions can operate under their operational design domain (ODD) and to guide infrastructure upgrades.

Keywords: road classification; infrastructure support for automated driving; ISAD; Cooperative, Connected and Automated Driving (CCAD); autonomous driving

1. Introduction

Automated driving implies that control of a vehicle gradually moves from human perception and human control of the vehicle to a partial or full control by computer systems, including environment perception. Automated driving requires certain prerequisites, which can be grouped into the following domains:

- the domain of the driver-machine interaction,
- the domain of the vehicle capability,
- the domain of the road operator, and
- the domain of law and regulation.

In recent years, these domains have been defined in more detail using the following classification schemes:

- the SAE levels [SAE J3016_201806], which describe the grade of automation and the related division of decision and control responsibilities between human driver and machine,

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- the Operational Design Domains (ODDs), which address the environmental conditions under which the machine functions operate, and
- the ISAD classification [Carreras et al. 2018, Amditis et al. 2019], which classifies the capability of road infrastructure to provide additional sensor information to vehicles, the so-called Infrastructure Support for Automated Driving (ISAD).

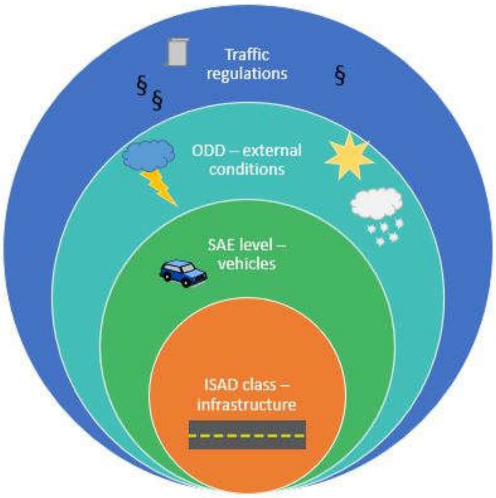

Figure 1: ISAD classes embedded in other domains

The joint stakeholder view (see Figure 1) on enabling connected automated driving on Europe's roads was first introduced in [ERTRAC 2019]. While the specification of ODDs is already under investigation [e.g. Kulmala et al. 2018 in EU-EIP Activity 4.2], this paper focuses on the ISAD classes and applies them to the Austrian motorway network. The underlying analysis will be based on the evaluation of sensor equipment of a specific road section, and on the available communication technologies between vehicle and infrastructure. Note that in this paper, it is assumed that the ISAD classes are a static definition, although in the future, it is imperative that the classification becomes dynamic, based on the quality and availability properties of the data path.

1.1. ISAD Classification

Within the ISAD classification scheme, there are five classes denoted by the letters A to E, where E represents no infrastructure support and A represents the highest infrastructure support level (see Figure 2).

	ISAD	Name	Infrastructure side	AV side	Digtial information provided to AVs: Digital map with road signs	VMS warnings, incidents, weather	Microscopic traffic situations	Guidance: speed, gap, lane advice
Conventional infrastructure	E	Conventional infrastructure / no AV support		Road geometry and road signs have to be recognized by AVs on their own				
	D	Static digital information / map support	Digital map data (including static road signs) complemented by physical reference points	Traffic lights, short-term road works and VMS have to be recognized by AVs on their own				
Digital infrastructure	C	Dynamic digital information	All static and dynamic information can be provided to the AVs in digital form	AVs perceive infrastructure support data				
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations	AVs perceive infrastructure support data in real time (C-ITS Day 1)				
	A	Cooperative driving	Infrastructure is capable of perceiving vehicle trajectories and guide single AVs (or AV groups)	AVs are guided by the infrastructure in order to optimise traffic flow (C-ITS Day 2+)				

Figure 2: ISAD class overview stating prerequisites and exchange data from infrastructure and AV side

1.1.1. ISAD E

For most of today's "conventional" infrastructure, in general, no digital infrastructure data is available, and therefore, no explicit AV support can be provided. The vehicle has to rely on the on-board sensor system exclusively and has no redundant second source of information. Additionally, the road geometry and road signs have to be recognized by automated vehicles on their own. This is denoted ISAD E in the ISAD classification.

1.1.2. ISAD D

If a road is classified as ISAD D within the ISAD classification, static digital information in the form of map support of this road section is available. Map support means that the infrastructure provider, the road authority or another relevant body supplies digital map data (including static road signs) complemented by physical reference points. However, automated vehicles will still have to recognize traffic lights, short-term road works and variable message signs (VMS) on their own. The provided data needs to be requested and downloaded by the respective map service provider in advance.

1.1.3. ISAD C

In order to be classified as ISAD C, "dynamic digital information" has to be available on the network in question. This means that information of dynamic road signs (e.g. variable speed limits) and dynamic information about warnings, incidents and weather warnings is available. A relevant message format, which is wide-spread in Europe, for such dynamic information is DATEXII [DATEXII].

1.1.4. ISAD B

The classification ISAD B requires the capability of "cooperative perception", which means that the infrastructure is capable of perceiving microscopic traffic situations and also of communicating to vehicles. Microscopic traffic data can be acquired by various sensor types. The infrastructure can react in real time and inform vehicles about traffic situations, e.g. via I2V communication using C-ITS messages as defined in [C-ROADS] and [ECo-AT].

1.1.5. ISAD A

For the highest classification ISAD A, the infrastructure has to be capable of perceiving vehicle trajectories and of guiding single AVs or AV groups. When driving on a road classified ISAD A, automated vehicles are guided and orchestrated by the infrastructure in order to optimize traffic flow. The corresponding messages sent out by the infrastructure comprise e.g. gap and lane change advice to control automated traffic. These advanced messages are referred to as C-ITS Day 2 for automated driving [Meckel 2019].

2. An initial ISAD classification of the Austrian motorway network

2.1. Defining a use case for Cooperative Guiding

The next generation of automated vehicles will struggle with the reliability of on-board sensor systems, the limitation of the perception horizon and the reliability as well as liability of decision making based on sensor data. In case a vehicle has no sufficient dataset to take decisions in a secured environment (at the edge of an ODD), it will force handover from machine driving to manual driving. This can potentially result in a critical traffic situation for the overall mixed traffic flow. If, however, a vehicle's on-board sensor system is supplied additional "virtual vehicle sensors", e.g. external data provided by the infrastructure, this may potentially prevent the vehicle or driving function from leaving the ODD (see Figure 6). Thus, in areas where a vehicle would need to operate on a lower SAE level, infrastructure can support by providing additional information, for example via a C-ITS message for a road works warning (see Figure 3). This further implies that a certain level of data quality has to be assured

Figure 3: C-ITS road works warning on dashboard of vehicle

at a certain level of service (ISAD class) since automated vehicles taking road infrastructure data into account have to trust and rely on every source of data. It has to be guaranteed that the Safety Of The Intended Functionality (SOTIF) can be validated within the development process of software-based driving.

2.2. Infrastructure equipment on Austria's motorways

Austria's motorways generally provide excellent ICT infrastructure. Based on their fibre-glass network and the existing equipment, a dedicated test track for autonomous driving, the ALP.Lab proving ground, has been installed on the motorway A2 near the city of Graz. A 3D model and HD map of the ALP.Lab proving ground have been prepared, and several additional digital and physical infrastructure elements have been installed, such as (see Figure 4):

- HD video cameras with traffic detection functionality (lane related),
- Traffic sensors allowing for single vehicle detection (lane related),
- Radar sensors (single-vehicle, track related), and
- C-ITS hybrid connectivity.

Figure 4: Example of available digital and physical infrastructure elements to provide additional information to automated vehicles

Since early 2018, ASFINAG has been able to send out standardized, harmonized C-ITS Day 1 messages on the test track. In May 2019, selected Day 2 messages for automated driving [Meckel 2019] were broadcast for the very first time. These messages aimed at guiding vehicles in specific traffic situations through speed, lane and inter-vehicle-gap recommendations as well as cooperative perception.

2.3. Preliminary Austrian ISAD classification

Combining the needs of automated vehicles and applying the ISAD classification, Figure 5 depicts a first fully automated classification of the Austrian motorway network based on the ASFINAG geographical information system database. All road sections fulfil at least the minimum requirements for ISAD D, i.e. digital map data with located static traffic signs. The highest ISAD class on the network is ISAD B reached on the 23 km long ALP.Lab proving ground near the City of Graz, equipped with the latest generation of sensors and C-ITS equipment. First tests with automated vehicles have already been performed, and further tests are on-going. The results are expected to give new insights into the required connectivity and supplementary information which need to be provided in order to reach the different ISAD classes.

Figure 5: Scheme of a possible ISAD classification of Austria's motorways

3. Summary

The ISAD classification will support automated vehicles to operate under a more predictable environment. While ODDs may get downgraded by a sudden change in the road topology layout, by heavy traffic conditions or under adverse weather conditions (see Figure 6), the infrastructure can support the vehicle's perception and close certain information gaps.

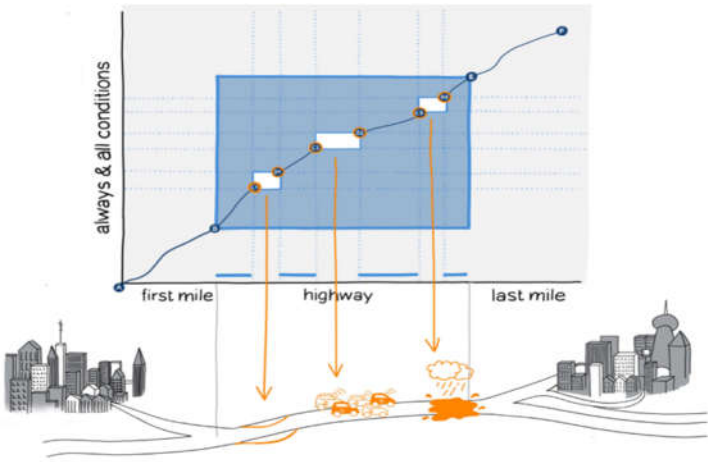

Figure 6: ODD scheme © Tom Alkim 2019

A first static analysis of the digital content capability of the Austrian motorway network was presented in this paper. Such an ISAD classification of a road network enables a systematic evaluation of road sections where automated driving functions can be operated within the vehicle's ODD and where infrastructure upgrades could be beneficial.

However, a reliable classification of the European network can only be developed through the elaboration of different practical examples to start the discussion with infrastructure and automotive stakeholders. The EC CCAM Single Platform already addresses this common goal, although the dynamic application of ISAD classes to the road network and respective mixed traffic management still needs to be addressed within the next years.

Acknowledgements

This work has been carried out as part of Measure 6.6 of the Automated Mobility Action Package of the Federal Ministry, Republic of Austria, Transport, Innovation and Technology.

4. References

Amditis, A., Lytrivis, P., Papanikolaou, E., Carreras, A., Daura, X. (2019). Road infrastructure taxonomy for connected & automated driving. Chapter 14 in: Lu, M. (ed.). *Cooperative intelligent transport systems. Towards high-level automated driving*, IET, pp. 309–325

Automated Mobility Action Package: Austrian Action Programme on Automated Mobility 2019–2022, available online at https://www.bmvit.gv.at/en/service/publications/downloads/action_automated_mobility_2019-2022_ua.pdf

Carreras, A., Daura, X., Erhart, J., Ruehrup, S., 2018. Road infrastructure support levels for automated driving. In: *Proceedings of 25th ITS World Congress*, September 17–21, 2018, Copenhagen. EU-TP1488.

C-ROADS, Harmonised C-ITS Specifications for Europe – Release 1.5, available online at https://www.c-roads.eu/fileadmin/user_upload/media/Dokumente/Harmonised_specs_text.pdf

DATEXII, available online at https://datex2.eu/,

EC CCAM Single Platform, available online at https://ec.europa.eu/transport/themes/its/c-its_en

ECo-AT Extended Release 4.0 System Specifications, available online at http://www.eco-at.info.

ERTRAC Connected and Automated Driving Roadmap (2019). EU CAD conference Brussels 2019, available online at https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf

Kulmala, R., Jääskeläinen, J., Pakarinen, S. 2018. The impact of automated transport on the role, operations and costs of road operators and authorities in Finland, EU-EIP Activity 4.2 Facilitation automated driving, available online at https://www.traficom.fi/sites/default/files/media/publication/EU_EIP_Impact_of_Automated_Transport_Finland_Traficom_6_2019.pdf

Meckel, P., 2019. Next generation C-ITS services to support automated driving. In: *Proceedings of 26th ITS World Congress*, October 21–25, 2019, Singapore.

SAE J3016_201806 Levels of Automated Driving, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*, 2019, available online at https://www.sae.org/standards/content/j3016_201806/

Seebacher, S., Datler, B., Erhart, J., Greiner, G., Harrer, M., Hrassnig, P., Präsent, A., Schwarzl, Ch., Ullrich, M.A., 2019. Infrastructure data fusion for validation and future enhancements of autonomous vehicles' perception on Austrian motorways. In: *Proceedings of 2019 IEEE International Conference on Connected Vehicles and Expo (ICCVE)*, November 4–8, 2019, Graz.