

Attributes of physical and digital infrastructure for highly automated driving from EU EIP and MANTRA

The subactivity 4.2 "Facilitating automated driving" of the EU EIP project supported by the Connecting Europe Facility (CEF) Programme of the EU, and the CEDR funded MANTRA project has during the past two years worked on the topic of physical and digital infrastructure for connected and automated vehicles. We have tried to understand what exactly are the demands of highly automated driving towards road operators, and have used the ODDs (Operational Design Domains) of the highly automated vehicles as our starting point.

The analyses and workshops of EU EIP and MANTRA have so far produced the list below for the ODD attributes identified so far based on information from vehicle manufacturers' and developers' own statements and reports (e.g. the [voluntary safety self-assessment reports provided to the NHTSA](#) in the USA), data from pilots and test sites, and papers and presentations by the stakeholders involved in CCAM developments around the world.

The list of ODD attributes produced in 2017-2019 by EU EIP and MANTRA (Ulrich et al. 2019)		
ODD attribute	Physical / Digital infrastructure	Static / Dynamic
Road	Physical	Static
Speed range	Physical	Static
Shoulder or kerb	Physical	Static
Road markings	Physical	Static
Traffic signs	Physical	Static
Road furniture	Physical	Static
Traffic	-	Dynamic
Time	-	Dynamic
Weather conditions	-	Dynamic
HD map	Digital	Static
Satellite positioning	Digital	Static
Communication	Digital	Static
Information system	Digital	Static
Traffic management	Digital	Dynamic
Infrastructure maintenance	Physical/Digital	Dynamic
Fleet supervision	Digital	Dynamic
Digital twin of road network	Digital	Dynamic

It should be made clear that the list above is focused on those aspects of the ODD that are relevant for the road operators. The top part of the attribute list can be regarded as strict ODD attributes, whereas the lower four items are attributes that support the existence of the ODDs or the operation of the vehicles in case of termination of the ODD.

The content of the attributes has been detailed further in the work of both projects. The lists of physical and digital attributes related to CCAM attempts to summarise the attributes and their sub-attributes so far identified can be found in the two tables below. The lists do not in any way indicate the willingness nor commitment of road operators nor other stakeholders to provide these attributes to the infrastructures.

Physical infrastructure attributes – proposal from EU EIP & MANTRA		
Infrastructure attribute	Sub-attributes	Comment
Road	Road type	Basic road types such as motorway, highway, street, private road indicate separation of carriageways, intersection arrangements, types of road users etc.
	Special road sections	Additional requirements for critical road sections such as tunnels, bridges, toll plazas etc.
	Separation of automated vehicles	Dedicated lanes or areas; permanent or temporary such as night time only
	Pavement of road	Ease of detection of the roadway
	Bearing capacity	Road (lanes, shoulders), bridges – critical for platoons
Speed range	Speed limit or recommendation	The speeds in which the automated driving system has been designed to function. Either static or dynamic speed limits/recommendations. Dynamic ones relate to traffic management
Shoulder or kerb	Wide shoulder	possibility to use as “safe harbour” if ODD ends
	Lay-bys or parking areas	as above
	Passenger pick-up/drop off areas	necessary for automated shuttles and robotaxis
Road markings	Existence of lane markings	lateral positioning
	Visibility, machine-readability	visibility to vehicle sensors
	Markings indicating use by automated vehicles	indicating of right to use or prohibition of use by highly automated vehicles
Traffic signs	Visibility, machine-readability	visibility to vehicle sensors
	Signs indicating use by automated vehicles	indicating of right to use or prohibition of use by highly automated vehicles
Road furniture	Landmarks	Static physical landmarks possible equipped by sensor reflectors or radio beacons or similar to support accurate positioning
	Gantries for road signs	indicating of right to use or prohibition of use by highly automated vehicles
	Gates and barriers	Access to dedicated lanes, roads or areas
	Road lighting	Support to automated vehicle’s vision system
	Game fences	Availability and condition
Infrastructure maintenance	Winter maintenance (snow removal, de-icing)	Visibility of road markings and traffic signs in adverse weather conditions
	Road maintenance incl. road marking painting, clearing of vegetation	Quality and visibility of road markings and traffic signs
	Inspections of infrastructure	Inspections according to standardised test/inspection protocols for both physical and digital infrastructure

Digital infrastructure attributes – proposal from EU EIP & MANTRA		
Infrastructure attribute	Sub-attributes	Comment
Communication	Short-range V2I	Communication at hot spots and road sections
	Medium and long-range V2I	Communications over road networks and corridors
	Medium and long-range V2I with low latency and wide bandwidth	Communications facilitating remote supervision of vehicles
Satellite positioning	Land stations	Improving accuracy of positioning in challenging areas
	Positioning support in tunnels	GPS repeaters or other solutions to provide accurate positioning also in tunnels
HD map	Maps of road environment including landmarks for camera, radar, and ultrasound sensors	Accurate positioning of the vehicle in the transport system, road and lane
	Maps of road environment including landmarks for LIDAR sensors	Accurate positioning of the vehicle in the transport system, road and lane
Information system (digital layer of the HD map)	Real-time event, roadworks, incident & other disturbances	Providing extended horizon beyond sensor range
	Digital traffic rules and regulations	Proving permanent and temporary rules of operation
	Geofencing information	Informing of access to specific roads, networks, and areas and/or right of use of specific automated driving use case
	Availability of physical infrastructure	Real-time information of the availability and usability of the physical infrastructure required for ODD
Traffic performance status on road network	Traffic status on network	Provides the transport system real-time traffic status information to the HD map
	Real time digital twin of the network managed including traffic flows	Enables simulation, modelling and testing of of different traffic management measures in order to select optimal measure for vehicle flows including also CAVs
Traffic management	Road works management	Standardised markings and processes to maintain ODD
	Incident management	Standardised markings and processes to maintain ODD
	ODD management	Management of factors affecting the ODDs of vehicles using the roads
	Traffic management centre and processes	Adaptation of the centres and processes to consider special requirements from automated vehicles and mixed fleets
Fleet supervision	Fleet monitoring and supervision centres	Remote monitoring and supervision of fleets, likely necessary for shuttles, robotaxis, roadwork trailers, maintenance vehicles

The physical and digital infrastructure are closely connected, for instance in the case of road markings and traffic signs the automated vehicles benefit from a "hybrid" combination both the physical markings and signs as well as their digital twins in digital maps.

A highly developed digital infrastructure without an appropriate physical infrastructure is not sufficient to fulfil the mobility needs of manually operated nor automated vehicles. Investments for further development of physical infrastructure need to be made considering the potentials of digitalization and the requirements of future vehicles with various degree of automated functions.

References

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