Decision-making process for (National) Road Authorities to invest in information support for Automated Driving Systems

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Abstract. Current Automated Driving Systems (ADS) immaturity causes a lot of uncertainty for road authorities as they cannot decide with confidence what is the best way to anticipate ADS development and deployment to preserve operational safety and efficiency on their road network. Typically, the actual competencies of ADS in the operating environment are not entirely known and ADS capabilities are regularly overestimated or underestimated based on assumptions that are derived from the scarce information that is publicly available. At the same time, many different situations can occur on open roads and in variable traffic and weather conditions, in particular when these roads are dynamically managed by the road operator (e.g. lane, speed and tunnel management). It is natural that National Road Authorities (NRAs) are concerned about the introduction of ADS that execute the complete dynamic driving task. The most constructive and perhaps only way forward is to create a dialogue between road authorities, automation system developers and regulators. The decision making process presented in this paper aims to support NRAs in this conversation and to break down the use case assessment in smaller elements.

Keywords: Automated Driving Systems, Operational Design Domain, Infrastructure support, Traffic Management, Decision-making, Road Authorities.

1 Introduction

A basic principle of Operational Design Domains (ODD) is that an Automated Driving System (ADS) continuously evaluates if it can operate in the local conditions based on the situational awareness it has. The Distributed ODD attribute Value Awareness (DOVA) framework as defined in [1] enables the ADS to benefit from off-board sensing infrastructure and data sources to become aware of ODD attribute values which it may not be able to measure or sense by itself. Typically, the earlier the information is available, the more options are possible for the ADS to respond (operational, tactical, strategic). The objective for making off-board information available is to enable timely transfer of the dynamic driving task to the driver in case of Level 3 ADS (and thereby decrease the risk of minimal risk maneuver in case the driver does not respond) or avoid the need for a transfer of control entirely. Whereas in case of Level 4 ADS the aim is to avoid the minimal risk maneuver or to achieve a safer minimal risk condition.

An important understanding related to the operation of ADS with the DOVA concept is that (only) the ADS decides if it is capable to handle the current local conditions based on its situational awareness. This has three implications for national road authorities (NRAs) that are regularly misunderstood:

1. Traffic management systems will not actively manage the tactical or operational decision making of ADS, i.e. activate and de-activate automation, instead its added value to ADS and thereby traffic safety lies in improving the situational awareness of ADS and providing strategic guidance.
2. The driving rules and expected driving behaviour must be defined in regulations such as the Vehicle General Safety Regulation and UN Regulations. ADS developers will define the ODD of their systems in line with the boundaries as defined by these regulations.
3. Information beyond the line-of-sight of vehicle sensors is relevant for timely anticipation of the downstream conditions. This is how NRAs can support ADS the most today, by providing information in advance. Currently there is no indication that ADS will comply with tactical and/or strategic guidance provided by e.g. a TMC. It could decide to follow strategic guidance regarding for example identifying the fastest route to take to reach a particular destination.

With these implications in mind it seems pivotal that the concerns and experiences of road operators are considered upfront and that ADS technology developers and road operators jointly interpret ADS regulations [2] to assess if known edge cases and known safety critical situations in day-to-day operations are sufficiently covered. In addition, regulations could provide a framework for ‘expected drivership’, which lets the ADS to decide if it can operate under a particular local conditions. Such a framework would specify the minimum driving skills and acceptable driving behaviour of ADS in a particular situation. In other words, it describes the rules of the roads an ADS must adhere to as well as the driving behaviour the ADS is supposed to reveal. This principle is discussed in [3] whereas this papers focusses on the role of NRAs.

2 Decision-making process for NRA role

Current ADS immaturity causes a lot of uncertainty for road authorities as they cannot decide with confidence what is the best way to anticipate ADS development and deployment to preserve operational safety and efficiency on their road network. How should they act? What investments to make? What information is most important to ADS and NRA core business? To support NRAs in creating a dialogue with automation system developers and regulators, the flow diagram below was developed [4] and aims to break down the assessment of any use case into smaller elements.

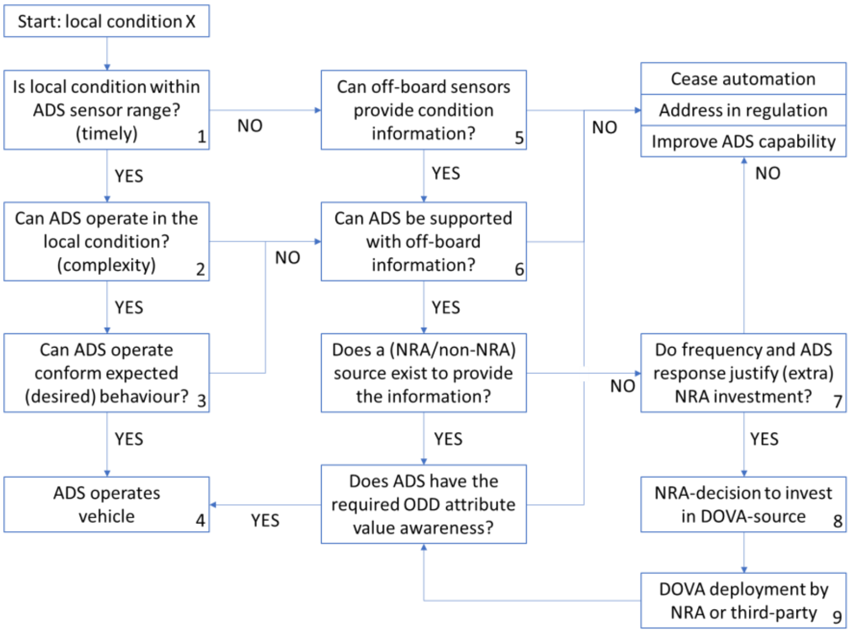

Fig. 1. decision-making process for NRA role.

For any given use case (i.e. the combination of a local condition of concern and an ADS), the first question to ask is (1) whether the local condition is within the ADS sensor range so that the ADS can respond to the condition in time. For example, a downstream traffic jam or weather condition is typically not within the sensor range of ADS. If the local condition is within the ADS sensor range, the next question (2) to ask is whether the ADS can operate in the local condition or not. In other words, is the local condition within the ODD of the ADS and when the ADS detects it, is the ADS able to handle the complexity of the situation? If the answer is positive, the third question (3) to consider is whether the ADS can operate the vehicle to conform with expected or desired driving behavior. Perhaps the ADS decides it can operate in the local conditions, but the resulting driving performance is poor, for example a (too) low driving speed and/or a (too) long response time. Clearly, the assessment of driving performance requires a benchmark to determine what is 'correct' and acceptable behavior as stated above. If all three questions are answered 'YES', the ADS can operate the vehicle also from the point of view of the NRA.

However, the answer 'NO' to any of the first three questions leads to another flow which is more NRA-oriented. The first consideration (5) is whether off-board sensors can provide information about the local condition of concern. If so, it is worthwhile to assess (6) if the ADS will actually benefit from off-board information in the particular local condition. If the situational awareness and/or decision making modules of ADS are not able to process and act on the information or it will not improve the driving behavior of the ADS, there is no point in making it available. Though, when both questions are answered positively and no (non-NRA) source exists that can provide the information, the NRA has to weigh (7) if the frequency of the local condition occurring and the impact of the ADS response to the local condition justify and require investment by the NRA. This is a policy and planning decision.

For this deliberation it is important that NRAs are well informed about ADS competencies, capabilities and driving behavior, as well as differences between high-end and low-end vehicles, current and future vehicle capabilities, and different brands of vehicles. With regards to the driving behavior of ADS more precise information about the minimal risk maneuver is needed, in particular what the minimal risk condition (MRC) is. The MRC is entirely situation dependent and represents the lowest risk action that can be taken under the current combination of vehicle and ADS failures, ambient conditions, current traffic density surrounding the ADS vehicle, whether a hard shoulder exists nearby and whether that shoulder is open or obstructed by other vehicle(s) or debris. From the NRA and traffic safety viewpoint it matters greatly if minimal risk condition in the case of ALKS means a full stop in the driving lane, or if it means to stop the vehicle on the hard shoulder or to continue driving the vehicle at 60 km/h. Finally, even when the frequency of occurrence and impact of the ADS response to the local condition justify exploring counter measures of some sort, it does not necessarily mean that NRAs are required to act. For some local conditions the sensible outcome may be that the ADS is inadequate and the logical solution is appeal to the vehicle manufacturer to improve the ADS capability. In case the questions 5-7 are answered ‘YES’ it means that the outcome is in favor of (8) a Distributed ODD attribute Value Awareness solution. As described in chapter 4 there are several governance options for NRAs to move forward at this point, ranging from the NRA doing the information collection, processing and distribution by the NRA to mandating a (trusted) third-party to fulfil this job. Either way, when the DOVA solution is present (9) and information about the local condition is available to the ADS, the ADS can operate the vehicle (3).

Lastly, the answer ‘NO’ to any of the NRA-related questions (5-7) leads to the outcome that the ADS must cease automation in the case of this particular local condition. This means that the necessary situation awareness cannot be obtained by ADS due to the absence of information, ADS are not designed to operate in the local condition or ADS adhere to the expected driving behavior standards. Depending on the observations made throughout the flow diagram, it may be appropriate to address the local condition in ADS regulation. For example because the situation is a special circumstance, safety critical, occurs frequently and/or has a high probability of causing undesirable behavior. As a consequence and as also stated above, in some cases there is a task for vehicle manufacturers to improve the capability of ADS.

3 Towards implementation: actor landscape

When it comes to the implementation of DOVA there are likely to be multiple stakeholders involved who each take one or more roles. To get a better understanding of these roles and how they interact, the actor landscape was studied [4]. Figure 2 shows the actor landscape and the actor relationships in a schematic and simplified way.

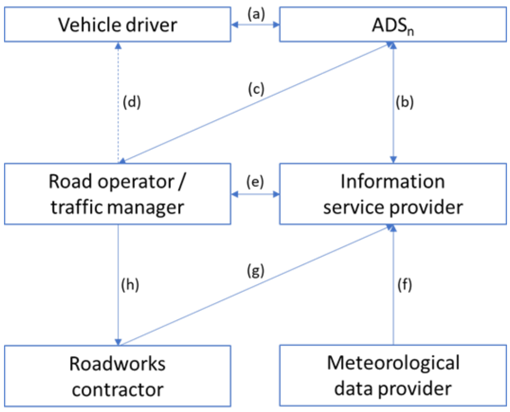

Fig. 2. actor landscape of DOVA use cases.

The role of the ADS is to perform the dynamic driving task and uses on-board and off-board sensors to create situational awareness. It can request the vehicle driver to take over the driving task (a) while the vehicle driver can activate and deactivate the ADS (a). The primary sources of off-board information are assumed to be the road operator / traffic manager (c) and the information service provider (b). Road operators/traffic managers can have different communication channels to publish information ranging from roadside signaling equipment to digital cloud-based solutions. They can provide information to vehicle drivers and ADS directly (c/d) and/or via information service providers (e). An information service provider can be a third-party information broker or vehicle fleet operator that facilitates the exchange of information between road authorities and fleets of vehicles, which are operated by either vehicle drivers or ADS. Information service providers can aggregate information coming from other specialist actors, such as roadworks contractors (g) and meteorological data providers (f). Roadworks contractors manage the road works site and can provide real-time information about of the location and topology of the site. Its contract with the road operator (h) specifies the obligatory actions that it needs to carry out. Meteorological data providers can provide real-time information about the location, type and severity of weather conditions (f). Another source of information for information service providers can be ADS (b), which can sense local conditions with on-board sensors and collect and provide probe vehicle data. Similarly, the road operator / traffic manager can benefit from this probe vehicle information once it is aggregated to obtain a better understanding of the local conditions on the road network (e). In fact, this information can enable the road operator / traffic manager to provide local condition information to other actors. Naturally, also other information flows likely exist such as information service providers providing information directly to the drivers via e.g. nomadic devices or meteorological data providers to road operators or traffic managers.

Conclusion

Exchange of information between automated vehicles and the infrastructure requires NRA investment. This paper provided a decision-making process for NRAs to help determine if they should act on a given local condition. The paper also discussed the actors involved in the implementation of DOVA. These results can be the starting point of a constructive dialogue between NRAs and ADS technology developers to establish a common vision and ambition. For example, in the short term the interested parties can express to work together on objectives such as avoiding unsafe driving of ADS and any disorder of traffic flow. For the medium term the interested parties might agree to collaborate on ADS overcoming limitations associated with DOVA. For the longer term perspective, the involved parties may aim for their mutual interests in the better management of traffic volumes and traffic flow dynamics, enabled by vehicle automation in case the penetration rate of ADS becomes sufficiently high.

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References

1. Khastgir, S., Shladover, S., Vreeswijk, J., Kulmala, R., Kotilainen, I., Alkim, T., Kawashima, H. and Maerivoet, S. (2023). Report on distributed ODD attribute value awareness, infrastructure support and governance structure to ensure ODD compatibility of automated driving systems. Traffic Management for Connected and Automated Driving (TM4CAD) Deliverable D2.1. CEDR's Transnational Research Programme Call 2020 Impact of CAD on Safe Smart Roads. March 2023.
2. European Union (2022). Commission Implementing Regulation (EU) 2022/1426 of 5 August 2022 laying down rules for the application of Regulation (EU) 2019/2144 of the European Parliament and of the Council as regards uniform procedures and technical specifications for the type-approval of the automated driving system of fully automated vehicles.
3. Maerivoet, S., Kulmala, R., Vreeswijk, J., Khastgir, S., Shladover, S., Alkim, T., and Kawashima, H. (2023). Recommendations for the dialogue between NRAs and automated vehicles developers. Traffic Management for Connected and Automated Driving (TM4CAD) Deliverable D5.1. CEDR's Transnational Research Programme Call 2020 Impact of CAD on Safe Smart Roads. March 2023.
4. Vreeswijk, J., Khastgir, S., Shladover, S., Maerivoet, S., Kawashima, H., Kulmala, R., Alkim, T. and Kotilainen, I. (2023). Implementation aspects of Distributed ODD attribute Value Awareness. Traffic Management for Connected and Automated Driving (TM4CAD) Deliverable D4.1. CEDR's Transnational Research Programme Call 2020 Impact of CAD on Safe Smart Roads. March 2023.