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Automated vehicles in commercial services – how to make it happen

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Abstract

Several entities in the world are carrying out tests, demonstrations and pilots of automated vehicles (AV) on proving grounds, closed areas and public roads. To proceed further, the situation varies in Europe regarding the use of AV in commercial services. Some countries allow payload (passengers, freight) and/or collection of revenue (ticket sale, cargo fees) for these operations; some do not – no commercial services are allowed. This is a regulatory obstacle for growth in numbers and deployment of AV in commercial services. Harmonisation and standardisation processes take time, while the industry, fleet owners and research world are desperately requiring procedures and criteria to start commercial public road services for passenger and cargo/parcel transport using driverless or remote operated AV. On a national level, AV approval for use in closer-to-markets and commercial services need to be solved. This paper discusses the procedures to bring special purpose AV closer to full market introduction.

Keywords:

Automated vehicles, commercial services, certification of automated vehicles

Setting the scene

EU vehicle approval framework

Existing EU legislation (COM (2018)) is to a large extent already suitable for the placing on the market of automated and connected vehicles. EU vehicle approval framework legislation, modernised in 2018, ensures a real internal market for vehicles - Member States cannot adopt national rules that contradict EU vehicle legislation - and a special procedure is foreseen for new technologies. The EU vehicle approval framework serves as a model for international harmonisation with our international partners.

Urge to have AV approved for commercial service

Several research and demonstration fleets of various levels of automated vehicles (AV) are rolling down the motorways, main highways, streets and closed areas in Europe and globally. This is possible since various national regulators and legislators have allowed the use of AV on public roads and streets for testing, demonstration and promotion purposes. In European Union member states, the national regulatory entities of road vehicle administrations have various procedures for automated vehicle owners, researcher entities and testers to demonstrate that their automated vehicles are “road worthy” –

not in the full sense of the term but at least fulfilling the minimum or at least modest safety requirements under full operational monitoring of a vehicle operator.

Homologation, harmonisation and standardisation

The homologation of AV according to global regulations is needed for their safe and reliable development and deployment. Existing regulatory safety frameworks for conventional vehicles and their components are insufficient to sufficiently assess the operational characteristics of AV technologies. As AV is becoming more and more a cyber-physical system that can operate without a human driver, new safety challenges are emerging and shall be addressed.

Harmonisation and standardisation organisations are working on the individual function tests of advanced driver assistance systems (ADAS), their approval methodology and accreditation of certification institutions for AV nationally and in Europe. The specific pain point here is the use of driverless shuttles or similar non-traditional AV. Traditionally the vehicle operator is sitting inside the vehicle; however, most future-oriented fleet owners – supported by their national authorities – may allow a (remote) operator to be located outside of the AV in a remote operator centre (ROC). In these cases, the remote operator must have continuous visibility and knowledge of the vehicle condition, operations and environment supported by low-latency two-way data communication connectivity, preferably over 5G or at least 4G LTE. Having said this, these procedures are valid only until the fleet owner is ready to take onboard paying customers or packages/cargo and to operate a commercial service on public areas and roads. This is how far the European exemption procedures allow to proceed.

Human driver inferential thinking vs. AI computational resources

Today’s automated vehicles cannot yet provide human-like inferential thinking. For AV to drive without human intervention, the information content from current sensors needs to be enhanced significantly, and this will create an increasingly large amount of data transmitted at huge data rates which, along with all the additional sensors, will quickly exceed the limits of in-vehicle storage space, and vehicle computational and energy resources (AI-SEE 2021). Because of this obvious challenge, the request to approve AV for public road and commercial service is incredibly effort-requesting set of tasks.

In summary, the current framework for AV approval assessment is significantly dragging behind many of the advanced technologies available in AV. Despite United Nation’s Economic Committee for Europe (UNECE) World Forum for Harmonization of Vehicle Regulations (WP.29) work on regulatory framework for AV, there are no regulations that currently address the safety and other relevant functionalities and systems of AV to allow the full approval before the actual deployment on roads.

Political estimations of AV operations

In May 2018, the European Commission adopted an *EU strategy for mobility of the future* (COM (2018)), and as part of this strategy, the Commission announced its intention to work with Member States on guidelines to ensure a harmonised approach for approval of AV on the roads (EC 2019). The focus on the *Guidelines on the exemption procedure for the EU approval of automated vehicles* identifies that AV are capable to drive in a limited number of driving situations (SAE levels 3 and 4). This kind of AVs are being tested and were expected on a commercial basis already by 2020 (COM 2018).

In (EC 2018), the Commission identified the automation use cases which are relevant from a public policy perspective for the next decade but will remain open to considering other possible new use cases.

- **Passenger cars and trucks** able to autonomously handle specific situations on the motorway: automation levels 3 and 4, in particular, highway chauffeur for cars and trucks, truck platooning convoys. Cars and trucks able to handle some low-speed situations could be in cities by 2020, such as rubbish trucks (working together with human employees) or valet parking (cars self-driving to a parking space). The capabilities of vehicles will then be further developed to satisfy increasingly complex situations (e.g. longer operating time or longer range with no driver input).
- **Public transport**, vehicles able to cope with a limited number of driving situations at low speed (automation level 4) are expected to be available by 2020 (in particular urban shuttles for dedicated trips, small delivery or mobility vehicles). These will most likely still require human supervision and/or operate on a very short range. The number of situations that these vehicles will be able to handle will then increase with time (e.g. a longer operating time or longer range with no human supervision, higher speed).

Based on ERTRAC (2017), they estimated that some cars, vans, trucks and buses of SAE level 3 and 4 should be available by 2020. However, they did not refer if they would be available also for real business and commercial services. As known, this is not the case yet in 2022 in numbers. Despite of this, each national road vehicle administration may have their specific approach and needs to allow driverless or remotely operated AV on the road. These exemption regulations apply only nationally and case by case. In December 2021, Mercedes got an international certification (UN Regulation No. 157: Automated Lane-Keeping Systems) for their Level 3 Drive Pilot (MER 2021). The system offers automated driving on certain type of German highways in speeds below 60 km/h. If the vehicle crashes during automated mode, the manufacturer assumes liability. Previously in 2021, Honda released a similar system for Japanese market (SLA 2021). There have been a few public transport cases that have received a national permit for operating on a fixed route: for example. in November 2021, EasyMile was authorized to operate a Level 4 shuttle but in France (EASY 2021).

Pushing forward

Until there are European testing, approval and roadworthiness specifications for driverless or remotely operated AV – instead of provisional approval exemption procedures – the European road vehicle administrations will approach this topic from their national viewpoints and only for their domestic roads. In order to fully benefit from driverless AV, they need to understand the procedures, progress and eventual results of various entities, namely for instance UNECE working parties, the entities mandated by European Commission, the entities supported by EU Member States, industrial lobbyist organisations and international standardisation organisations' progress.

We need to add on top of those also the needs, work and targets of automotive, special purpose vehicle (e.g. automated shuttles) and work machine manufacturers, their suppliers, research institutions and fleet operators in order to proceed towards driverless AV that would be allowed also for commercial services on public roads. These are more than challenging issues within a sector but more so across all sectors for administrations. The above-mentioned EC guidelines surely smoothen the way ahead, but they are not sufficient from several viewpoints, not to mention the liability aspects of fleet operators.

The UN Regulation No. 157 on automated lane-keeping systems was an important step in enabling the first products. Such incremental ADAS-type standardisation was generally expected to happen first, and while such work is not comprehensive, it can provide building blocks for broader automation.

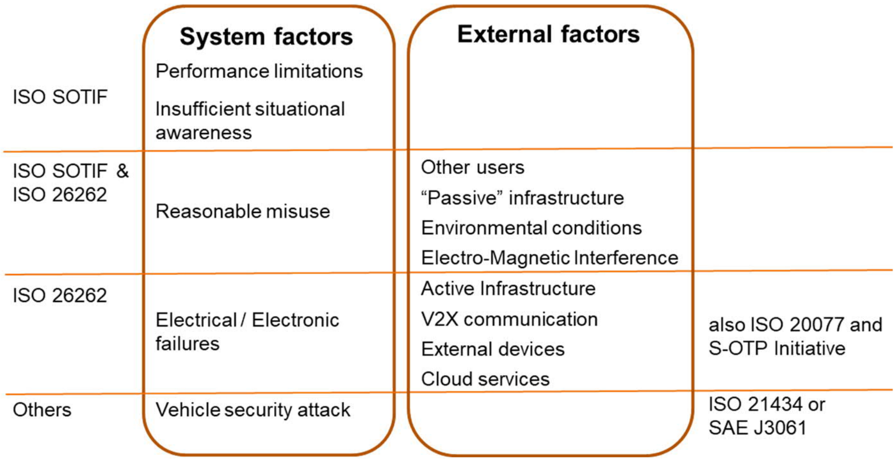

Figure – Some of the AV approval relevant factors and applicable standards.

The general objectives are to search for common grounds for the road vehicle administrations how to set various requirements for approval process, how to define the actual AV approval tests and what to require from the vehicle manufacturers' and fleet owners' approval requests for their driverless shuttles and work machines. The order of these steps may vary from case by case, but the big issues are still not clear for any of the actors of automated vehicle operations.

Essential steppingstones

There are several phases how to build up the framework for driverless AV acceptance for commercial services. First, we need to understand current and near future work and results of UNECE and standardisation organisations. Second, we need to understand the overall European framework for AV usage for connected and automated mobility (CAM) services. Third – but not least – we need to understand the current research and development environment and the overall urge to proceed to commercial AV services. Research is important, pilots are useful, but the commercial services will be the ultimate steppingstone for global AV adaptation to replace today's human-driven diesel- and petrol-powered traditional cars, vans, utility vehicles, work machines, buses, lorries and trucks.

The scope of the approval and certification domains consist of extensive research of connected and automated vehicles (CAV) combined with a thorough literature review of the domains in question covering a.o. UNECE, standardisation, research, regulatory and roadworthiness domains. Adding up these two streams, this programme is to facilitate establishing a certified entity for driverless AV approval for commercial services on public roads.

Current AV exemption approval framework

The current regulatory framework for assessing the performance and safety of vehicles and their respective technologies represents a mixed combination of national and international legislation, regulations, and industry accepted standards. At the core of this framework is UNECE WP.29, which is charged with creating unified automotive standards and regulations to facilitate international trade. Currently, in WP.29 approximately 100 separate regulations applicable to passenger vehicles have been developed, consisting of vehicle safety, energy efficiency, theft resistance and environmental issues. Regulators rely on the WP.29 regulations for their national vehicle testing and certification requirements. We can already validate new and ground-breaking vehicle automation technologies under the EU vehicle approval framework. Nevertheless, technologies not foreseen by current EU rules can be approved through the so-called EU exemption – granted based on a national ad-hoc safety assessment. The EC Guidelines for approval exemptions (EC 2019) help coordinating national ad-hoc assessments of AV. These guidelines provide overall framework for EU Member States to follow in their ad-hoc safety assessments. This ensures coordination in the approval of autonomous technologies. It also supports a more general discussion on how to regulate AV in the future. The EC Technical committee – motor vehicles (TCMV) endorsed these guidelines in 2019. The guidelines also aim to clarify to manufacturers what they can expect from regulators, harmonise regulation with international partners and start a discussion on the necessary adaption of some national legislation for these vehicles.

The guidelines consist of eight specific domains the AV manufacturer is to address for the exemption approval, namely

- system performance in the automated driving mode, covering automated systems, environment perception and dynamic driving task and interaction with other road users
- driver/operator/passenger interaction
- transition of the driving tasks
- minimum risk manoeuvre
- installation of event data recorders
- cybersecurity (not covering cyber-attacks)
- safety assessment and tests
- information provision to automated vehicle users.

As such together with some brief supporting text, the guidelines leave the actual requirements for testing procedures and acceptance criteria quite open. More content for AV approval comes – naturally – from various working parties and groups of EU together with the Member States, UNECE together with their member states' representatives, and international standardisation organisations together with the industrial members and lobbyists. Globally, these entities shall provide the actual full approval framework including the full scope of requirements, procedures and approval criteria. However, this will take still years and years to achieve the full maturity of the official documentation.

Issues that road vehicle administrations are facing

As discussed above, due to the complexity of AV certification and approval, road vehicle administrations are obliged to deal with multitude of disciplines that they do not need to assess concerning traditional road vehicles. Because of this, the administrations may find it challenging to set realistic, sufficient but not overshooting targets and objectives for AV certification testing and procedures for the manufacturer to show applicable evidence that their AV is fulfilling the (basic) requirements for conformity testing. Another scope of challenges is arising from the absence of the generic requirements for declaration of conformity since this is not finalised especially for driverless AV domain. Thus, usually without deep knowledge and experience in AV research, development and testing the vehicle administrations may find it rather diligent to gain skills and competence on how to define AV conformity testing prerequisites and requirements, performance testing procedures, performance indicators and acceptance criteria. From a regulator/legislator perspective, it is rather awkward to combine the issues arising from legislation, regulations, standards and research possibilities and results. Also, how to apply the issues coming from all these aspects may prove rather cumbersome.

Topics putting pressure on understanding the complexity of certification

Scenario-based approach

UNECE WP.29 adopted a framework document on automated/autonomous vehicles. The framework document included gave the mandate to draft a new assessment/test method for automated driving (NATM) (GRVA 2021). Once the NATM has reached a state of maturity to inform evaluation criteria based on performance requirements, it is anticipated that this document (and any supporting resources) will be used to help inform validation process guidelines and/or regulations/requirements needed. NATM adopt a multi-pillar approach for the validation of ADS, composed of a scenarios catalogue and five validation methodologies. NATM relies on scenario-based validation methods. In brief, the scenarios are classified in three categories, namely functional, logical and concrete scenarios.

Functional Scenario have the highest level of abstraction, outlining the core concept of the scenario, such as a basic description of the ego vehicle's actions; the interactions of the ego vehicle with other road users and objects; roadway geometry; and other elements that compose the scenario (e.g. environmental conditions etc.). This approach uses accessible language to describe the situation and its corresponding elements.

Logical Scenario contains selected value ranges or probability distributions for each element within a scenario (e.g., the possible width of a lane in meters). The logical scenario description covers all elements and technical requirements necessary to implement a system that solves these scenarios.

Concrete Scenarios are established by selecting specific values for each element. This step ensures that a specific test scenario is reproducible. In addition, for each logical scenario with continuous ranges, any number of concrete scenarios can be developed, helping to ensure a vehicle is exposed to a wide variety of situations.

Use case-based approach

To proceed forward and to understand properly what conformance testing should provide, we need to understand where we are starting from and what we are targeting at. There is an applicable three step definition mechanism consisting of what are the use cases (comparable to concrete scenarios above) that AV certification should address, which test cases should provide best response to performance indicators and impacting factors of AV manoeuvring in public roads (SOTIF 2019). This combination of topics forms an environment that shall be assessed.

Use cases provide the specification of generalized fields of application, possibly entailing the following information about the system: one or several operational and functional scenarios, functional range of use, desired behaviour of AV, and system boundaries that enable a targeted and repeatable execution of the tests.

Test Cases form sets of conditions to determine if a system is working according to its intended functionality. A test case entails a (logical) scenario, specific set of impacting factors and parametric values for each aspect of the scenario, together with the pass-fail criteria on which to evaluate it.

The **impacting factors** – as defined in (SOTIF 2019) – form the basis for use case definitions, like definition of the triggering event, potentially hazardous behaviour of the system, identified hazard, operational situation to cause harm, reactions of involved parties and the potential harm incurred. The impacting factors like identified hazard and operational situation help us to understand the probability of a potential risk for AV operation. On the other hand, probability together with reactions of involved parties gives us elements of controllability of the risk involved.

There are several jointly funded European projects working on the CAM domain, each from their specific point of view and functionalities and sub-processes. However, none of these are working directly on the homologation or certification process at large.

European project examples

AI-SEE (Artificial Intelligence enhancing vehicle vision in low visibility conditions, EUREKA No. 20008) is investigating sensing solutions and automated driving support functions in adverse weather ODDs. The project has been conducted testing campaign in North of Europe and discovered impact of cold weather to sensing data quality. Sensing system performance needs to be iteratively tested in same conditions and therefore, special test setups and digital twins are designed. (AI-SEE 2021)

AWARD (All Weather Autonomous Real logistics operations and Demonstrations, Horizon 2020, No 101006817) safety concept activities of the Autonomous Driving System will follow state-of-the-art from various standards in order to cover safety and security topics. AWARD is paving the way for the roll-out of driverless transportation, whatever the weather conditions are. It will deploy safe and efficient connected and automated heavy-duty vehicles in real-life logistics operations. AWARD Members will also use all the data obtained from previous use/development of significant ADS, while extending the ODD and related conditions to improve its performance on safety and availability. (AWARD 2022)

L3Pilot (Level 3 driving automation, Horizon 2020, No 723051) tests the viability of automated driving as a safe and efficient means of transport on public roads. It will focus on large-scale piloting of SAE

Level 3 functions, with additional assessment of some Level 4 functions. The functionality of the systems will be exposed to variable conditions with 1,000 drivers and 100 cars across ten European countries, including cross-border routes. The technologies being tested cover a wide range of driving situations, including parking, overtaking on highways and driving through urban intersections. The tests will provide valuable data for evaluating technical aspects, user acceptance, driving and travel behaviour, as well as impact on traffic and safety. With the comprehensive piloting of automated driving functions in test vehicles, L3Pilot will pave the way for large-scale field tests of series cars on public roads. The project has not carried out any public validation. (L3Pilot 2022)

Understanding the overall scope of AV safe operation

To have a basic understanding of the complexity of automated driving safety, we would need to be able to define the utmost important issue [ref. step 1 in the Figure below] of how safe must SAE level 3 and 4 AV systems be. This is the most important topic of discussions of and between legislators, regulators, AV practitioners, AV industry, psychologists, behavioural analysts, and scientists of all branches. Now that safety margins can be programmed, who can state what should they actually be. What do the legislators mean, mathematically speaking, by driving carefully near children.

As anticipated, we do not have an answer for this to continue forward with practicalities defined in the figure below. Anyway, we shall not stop there even if driving on a thin ice.

Next we refer to what aspects are necessary to achieve the overall AV safety vision [ref. #2]. Here we are not talking only about driving safety or vehicle safety but all aspects of safety, including cybersecurity. We are stepping into unknown environment of cybersecurity (and cyber-attacks).

When utilising Safety by design approach we first take on details of the operational and functional level [ref. #3]. We need to understand the nature, structure and operational and functional aspects of AV systems capabilities. Another dimension is to understand and verify the capabilities needed to cover all aspects of automated driving.

On the technical level [ref. #4], we need to concentrate on those building blocks that are needed for safe operation of AV. The challenges remain to define the actual building blocks that must be assessed, verified and validated.

Even if specific architectures (software, hardware, communication, functional) are defined to build up the AV capabilities and elements and to build the overall system, we need to be able to define and agree on how to design the overall architecture [ref. #5] out of the required and defined building blocks.

In this model and based on the system design, the AV systems' verification and validation (V&V) are required [ref. #6]. Without extensive research, development and innovation experience this will remain as the biggest single challenge for the road vehicle administrations. In a simple format: what and how to verify and then how to validate the selected sets of elements, capabilities, functionalities and operational capacities of AV are fulfilling the conformity requirements. This is another topic that shall not and cannot be addressed in a single research paper. However, in the context of this paper, V&V processes are building upon the results of several European funded AV and CAM research projects. The projects have defined and established their V&V procedures and processes for their specific topics so that the very heterogenous consortia and partnerships have been able to agree upon the solutions and outcome. Certainly, most tests so far have included human observation as part of the safety solution.

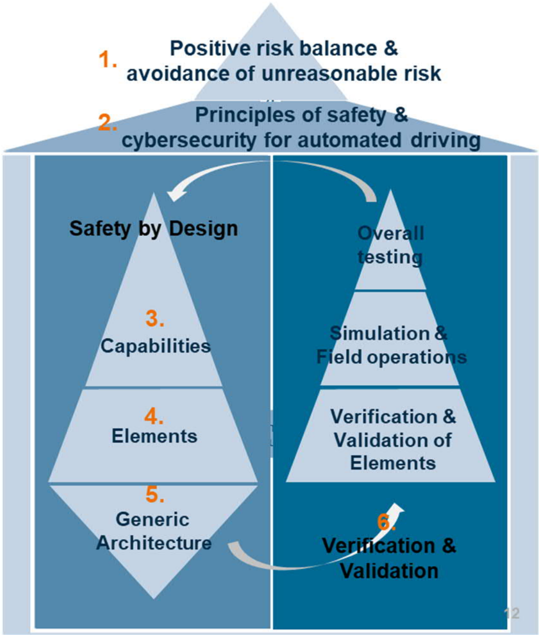

Figure – Domains of safety. Ref: combined from © ISO 26262 & ISO TS 5083

Conclusions

Significant investments will be needed to develop the relevant technologies, to create the necessary infrastructure support and to ensure social acceptance for automated mobility. While most of the investment will come from the private sector, the EU provides significant stimulus for research and innovation and for deployment of targeted infrastructure (COM (2018)).

To be able to address the AV certification in near future, the AV practitioners need to join forces in order to establish a framework for national and eventually European certification procedures and processes for AV approval for use in commercial services. Currently in Europe – as well as in the whole world – there are hundreds of experts, regulators, legislators, civil servants, researchers, scientists and industrialists putting enormous amounts of work on development of a regulatory framework of testing, approval and certification of AV conformity testing requirements and processes. This will not be solved overnight because the difference between human and automated is so great. However, there are another hundreds of researchers, industrialists, scientists and innovators developing special purpose AV that could be used in commercial services for passenger and cargo transport in urban areas and European road networks. However, approvals are pending due to lack of official tests, requirements, performance indicators, approval criteria, models for verification and validation, and eventually certification procedures. We recommend that the work first focuses on determining mathematical safety margins and adapting them to different situations and scenarios. These safety margins must guarantee almost absolute safety. Such mathematical "traffic laws" would allow further standardisation such as the UNR157 on lane-keeping and other careful automated operations at low speeds.

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