Paper number ITS-TP1762

Driver training and testing in the era of automated driving: Status quo and future directions

Cornelie van Driel[1*], Arie Paul van den Beukel[2], Nina Veders[3], Chris Huijboom[3]

1. Rapp Trans (DE) AG, Berlin, Germany, cornelie.vandriel@rapp-trans.de

2. University of Twente, Enschede, the Netherlands

3. HAN University of Applied Sciences, Arnhem, the Netherlands

Abstract

The wait-and-see attitude from the past years seems to slowly disappear when it comes to licensing drivers of automated vehicles. Where it was previously believed that vehicle automation would make the driving task easier, it is now being recognized that it also introduces new tasks for which additional driver skills and knowledge are necessary. It is anticipated that driver training and testing need to be adapted. Although the topic is raised by many stakeholders, relatively few concrete research and policy activities can be found today. This paper presents the status quo and discusses future directions for driver training and testing with a focus on the Netherlands. Continue focusing on the overall impact of driver behaviour on safe and efficient participation in traffic, regardless of whether a driver uses vehicle automation, highly underestimates how much influence (also lower-level) vehicle automation has on the desired skills of a driver using such systems.

Keywords:

Automated driving, Driver training, Driver testing

Need for new driver training and testing

The wait-and-see attitude from the past years seems to slowly disappear when it comes to licensing drivers of automated vehicles [1]. Depending on the level of automation, the role of the human driver changes, e.g. from being an active operator to being a passive supervisor of automation. However, these two roles require different training and skills [2]. It is expected that driver training and testing will need to change significantly, for example acknowledged by FERSI in their Code of Principles for "Safety through automation" [3]. Moreover, there is a need to properly inform and educate drivers on in-vehicle technologies. For example, a large-scale survey among business drivers in the Netherlands revealed that these drivers barely knew which driver assistance systems were fitted in their car, and if they did, how they should use them [4]. A common method for learning to use in-vehicle technologies

appears to be trial-and-error [4], [5]. In these cases especially driver training could fulfil an important role.

For the time being, automated vehicles still require a great deal of human judgment and skill to operate safely. That is why existing licensing and training procedures have not changed in recent years and why most research efforts are addressing driver performance and behaviour in automated driving conditions which require the human driver to be ready to take back control when the automated systems requests so (Level 3 "Conditional Automation"[1]). However, the authors truly believe that much more emphasis should be put into including also lower-levels of automation in current driver training and testing procedures so that drivers know about the automation's capabilities and expected actions and how they are to use automation in a safe and acceptable manner.

The topic of new driver training and testing is globally raised by many stakeholders and integrated in European calls for research proposals (e.g. Horizon 2020). However, relatively few concrete policy and research activities can be found today. It is time to investigate and discuss the consequences of the deployment of automation for the existing schemes for training, testing and licensing of drivers. This paper can be considered a first step and presents the status quo and future directions.

State-of-the-art on the development of automated driving systems

Automated driving is seen as one of the key technologies influencing and shaping our future mobility and quality of life. The main drivers for (higher levels of) automated driving are [6]:

- Safety: Reduce accidents caused by human errors.
- Efficiency and environmental objectives: Increase transport system efficiency and reduce time in congested traffic. Also, smoother traffic will help to decrease the energy consumption and emissions of the vehicles.
- Comfort: Enable user's freedom for other activities when automated systems are active.
- Social inclusion: Ensure mobility for all, including elderly and impaired users.
- Accessibility: Facilitate access to city centres.

Development and deployment

Fully automated driving does not happen overnight. Especially when considering systems for passenger cars and heavy vehicles, the guiding principle is evolution instead of revolution. In other words: from Advanced Driver Assistance Systems (ADAS) to fully automated driving (see e.g. [7]). The deployment roadmap of automated vehicles is highly linked with many other topics, such as

[1] According to standard SAE J3016 from no driving automation (Level 0) to full driving automation (Level 5). The levels of driving automation are primarily defined by reference to the specific role played by either the human driver or the automated driving system in performance of the dynamic driving task.

regulation, technology development and business models.

Since 2000, the automotive industry has introduced many ADAS features (Level 1) on the market [8]. Driver assistance technologies, such as adaptive cruise control (ACC), advanced emergency braking, lane departure warning and blind spot monitoring are now commonly offered by many manufacturers in their new vehicles. The demand for ADAS is expected to increase at a stellar rate in the coming years [9]. Partially-automated driving in specific situations (Level 2) is starting to become available on a growing scale. Currently the transition from partially-automated vehicles to conditionally-automated vehicles (Level 3) which can take over the driving and monitoring task under specific scenarios allowing the driver to be "disengaged" is taking place[2].

Mandatory systems

Many safety technologies are already mature and ready for generalized deployment [11]. In fact, advanced emergency braking and lane departure warning are mandatory for all new trucks and buses under the EU type-approval requirements since 2014. In order for society to fully profit from such technologies, the European Commission proposed on 17 May 2018 a review of the General Safety Regulation to mandate the fitting of a set of safety functionalities for all new vehicles (see Figure 1). In March 2019, the European Parliament and the Council reached a provisional agreement on the proposal, which clarifies exact requirements for different safety features and brings forward the deadlines for their mandatory instalment in vehicles. Parliament is expected to soon vote on it.

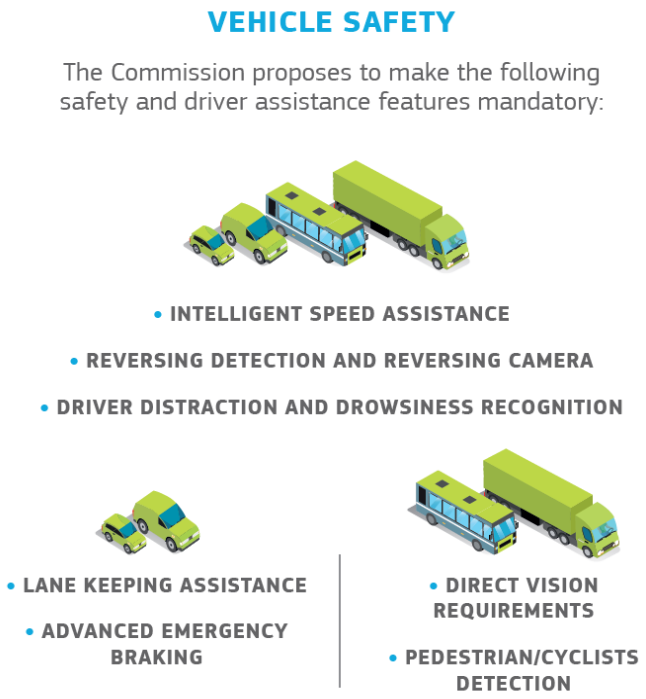

Figure 1 - Mandatory safety features on new European vehicles

[2] Although a growing number of car makers are considering skipping Level 3, see e.g. [10].

Mixed vehicle fleet

For the time being, the gradual deployment of automation will result in a mixed vehicle fleet on our streets, consisting of traditional vehicles without any form of driver assistance up to upper class cars that are able to drive themselves and monitor the environment in some instances. Moreover, for each Operational Design Domain (ODD; e.g. highway driving, self-parking, geofenced urban driving) a vehicle could have a separate automated driving system. Hence, a vehicle could have multiple systems, one for each ODD [12]. Since many automated driving systems will need to be activated by the human driver, this further diversifies the mixed vehicle fleet.

Current span of allowed testing of and driving with automated driving systems

In October 2015, Tesla introduced an Autopilot feature that allowed for minutes of hands-free driving on highways [13]. However, subsequent software updates restricted hands-free driving to a few seconds. Inspired by the role of legislation in the example above, it is worthwhile to consider and better understand the current span of allowed on-road testing and driving with automated driving systems by having a look into the current legislation.

The "switch" between Level 2 and Level 3

Level 0-2 systems rely on a human driver to monitor the environment. With Level 3 systems there is a "switch" in responsibility, since for these systems it is assumed that the automated driving system monitors the environment. Still a human driver must be prepared to take over the dynamic driving task when the system requests him to. This "switch" can also be seen in most current legislation related to driving with automated driving systems.

Current law usually covers the use of Level 0-2 systems without explicit amendments. This was recently confirmed in a Dutch court ruling stating that the driver of a Tesla with activated Autopilot function (Level 2) is the person who has the power over the vehicle (and not the Autopilot as was claimed by the driver who was fined for holding a smartphone while driving)[3]. From Level 3 onwards, special regulations are being considered, see for example the legal framework in Germany on conditional (Level 3) or highly (Level 4) automated driving functions, adopted in June 2017[4]. In the US the proposed framework regulates the use of autonomous vehicles from Level 3 onwards [14] – although several stakeholders urge the need to include Level 2 in the framework as well [15]. Notable

[3] https://www.rechtspraak.nl/Organisatie-en-contact/Organisatie/Rechtbanken/Rechtbank-Midden-Nederland/Nieuws/Paginas/Mens-is-feitelijke-bestuurder-auto-ook-in-Tesla-met-autopilot.aspx

[4] Achtes Gesetz zur Änderung des Straßenverkehrsgesetzes, Bundesgesetzblatt Teil 1, Nr. 38 vom 20.06.2017

is that for the operation of an autonomous vehicle[5] a special driver's licence endorsement was initially proposed in the State of Nevada based on a determination of "the competency and eligibility of the person to operate an autonomous vehicle in autonomous mode". However, this endorsement has been eliminated in the revised proposed regulation of motor vehicles in March 2018.

This "switch" between Level 2 and 3 can also be seen in current regulations on on-road testing of automated driving systems, see for example standard SAE J3018 with guidelines for safe on-road testing of prototype automated driving systems of Level 3 onwards. Testing regulations usually go one step further than current legislation for the normal operation of automated vehicles. For example, special regulations already exist for testing driverless cars. Note that for the testing of higher level automation, the focus is much more on software environments and simulations than on human test drivers.

Generally, manufacturers need to maintain a training program for their test drivers. These training programs appear to be quite different among manufacturers regarding content, intensity and duration. Still, some of the elements in these test driver training programs could be inspirational with respect to future driver training and testing, e.g. classroom lessons on the abilities and limitations of automated vehicle technologies, computer simulations of failures and real-world driving sessions.

Legislative context of licensing the driver in Europe

Directive 2006/126/EC on driving licences sets out the provisions concerning licensing drivers at European level. The Third Directive on Driving Licences entered into force in January 2013 and sets out minimum requirements for driving tests. Member States shall take the necessary measures to ensure that applicants for driving licences possess the knowledge and skills and exhibit the behaviour required for driving a motor vehicle. The tests introduced to this effect must consist of:

- a theory test, and then
- a test of skills and behaviour

The conditions under which these tests shall be conducted depend on the driving licence category. For example, the content of the theory test for category B does not include any explicit provisions concerning automation technology, except perhaps "rules regarding vehicle use in relation to the environment" regarding "appropriate use of audible warning devices". Also the test of skills and behaviour for category B does not include any such provisions. Applicants must demonstrate that they are capable of driving safely by satisfying certain requirements related to:

- Preparation and technical check of the vehicle with a bearing on road safety

[5] "Autonomous vehicle" means here a vehicle that can be driven without the active control or monitoring of a human operator, i.e. Level 3 or higher.

- Special manoeuvres to be tested with a bearing on road safety
- Behaviour in traffic

The vehicles used in tests of skills and behaviour shall comply with the minimum criteria set out in the Directive. Member States may make provisions for more stringent criteria or add others. For category B the only technical criterion is a vehicle capable of a speed of at least 100 km/h.

Review of Directive 2006/126/EC

Four years after the entry into force of the Directive, an assessment of the introduced novelties in achieving the objectives of the Directive was conducted on behalf of the European Commission [16]. Among others, it was stressed to remove obstacles to the deployment of vehicles with driver assistance systems, e.g. by requiring knowledge of such systems by driving examiners and instructors and including (semi-)autonomous driving in driver training and the examination procedure.

Similar recommendations were stressed in a separate study on driver training, testing and medical fitness conducted on behalf of the European Commission [17]. This study emphasizes, that the pace of technological advancement is fast, and driver testing is not keeping up with this. It is recommended that the EC should aim to raise awareness among Member States that the driving task is rapidly changing due to new technologies (e.g. navigation systems, adaptive cruise control, lane keeping systems, inattention warning systems, semi-autonomous driving systems), and that safe and adequate use of these systems needs to be learned during basic driver training, and if possible be tested.

Among others, the International Commission of Driver Testing CIECA is discussing potential future steps for the revision of the Driving Licence Directive, esp. with respect to passenger cars (for heavy vehicles amendments have already been incorporated into a new directive – see below). Also the Commission is seeking voluntary commitments, for example from driving schools, e.g. training new and existing drivers and riders in how to use new vehicle safety features [11].

New Directive for professional drivers

The recently adopted Directive (EU) 2018/645 includes the minimum qualification and training requirements regarding the use of in-vehicle devices such as driver assistance or automation devices. Now professional drivers must know the technical characteristics and operation of the safety controls in order to control the vehicle, minimise wear and tear, and prevent disfunctioning use of electronic and mechanical devices such as Electronic Stability Program (ESP), Advanced Emergency Braking Systems (AEBS), Anti-Lock Braking System (ABS), traction control systems (TCS) and in-vehicle monitoring systems (IVMS) and other, approved for use, driver assistance or automation devices.

Current practice of driver training and testing in the Netherlands

Directive 2006/126/EC is transposed into national Dutch law[6]. CBR is the organisation appointed by the Ministry to apply the tasks in the area of assessing driving ability, including the education of driving examiners.

Driver licensing

The current approach to test driving proficiency in the Netherlands comprises of a theory test and a practical driving test of ca. 45 minutes in real traffic. The Dutch handbook for driving examiners and instructors describes the most desirable driving behaviour of car drivers (category B) which needs to be shown during the practical driving test in order to receive a driving licence [18].

For the assessment of a candidate driver's performance the CBR uses a matrix which plots 7 elements of road traffic participation (i.e. exam components, e.g. driving on straight and curvy road sections, behaviour near and at intersections, special manoeuvers) against 13 driving 'sub' tasks (i.e. assessment topics, e.g. speed control, braking/stopping, distance keeping, giving way, anticipation, acting on traffic rules) (see also [19]). Only few of the assessment topics may be considered operational tasks, the majority consists of tactical tasks. All tasks are a subset of the main objective to safely participate in traffic. The assessment is based on a qualitative appraisal of the shown competences to take part in traffic. Overall it comes to the examiner's subjective judgement whether the 'overall picture' of demonstrated skills in the different situations make up a sufficient level of driving proficiency.

There is no obligation towards specific safety features in the vehicles used for the practical driving test[7]. Since 1 January 2016, candidates are allowed to use ADAS (except automated parking) during the driving test on a voluntary basis. If so, they will be judged on using these systems in relation to a proper performance of the driving task. There are no specific assessment criteria towards using ADAS. Regardless of whether a candidate uses vehicle automation, the assessment focuses on the overall impact of driver behaviour on safe and efficient participation in traffic. Hence, it is not deemed important what tools a candidate may use or not, in the end it is only about displaying safe traffic behaviour.

ADAS in the driving test?

In the recent five-year evaluation of the CBR, commissioned by the Ministry of Infrastructure, it was concluded that the CBR lags behind in the field of innovation regarding vehicles that become

[6] In particular "Wegenverkeerswet 1994" and "Reglement rijbewijzen". For drivers of heavy vehicles also "Regeling vakbewaamheid bestuurders".

[7] Since September 2011, every exam vehicle must have a navigation system. From 25 March 2019 onwards, the use of a navigation system will be a standard component in the Dutch driving test.

increasingly autonomous [20]. More effort by the CBR and the Ministry is needed to assess the impact of these developments on driving behaviour and road safety in order to timely adapt primary processes and legislation. Consequently SWOV and CBR conducted a survey among driving schools and driving examiners about driving assistance systems in driver training and the driving test for driving licence B [21]. The recently published report includes relevant results on the presence of ADAS in driving school vehicles and the use of these ADAS during training and the driving test. It also presents interesting opinions of driving instructors and examiners on the need to include ADAS in future driving training and testing procedures. The driving examiners are almost unanimous in the opinion that learner drivers should be trained in driving with the most common forms of ADAS. They also believe that the theory test should include questions about these ADAS. However, they are slightly less pronounced when it comes to including these systems in the driving test, although more examiners are in favour than against.

Since ADAS are not being assessed in the current licensing procedures, this significantly impacts driving schools not to opt for ADAS when buying their fleet or train their candidates in understanding and using these systems in case their vehicle is equipped. Only on a voluntary basis some driving schools provide education on ADAS (e.g. Prodrive Academy, Veronica Verkeersschool, several driving schools jointly offering DAF Euro 6 training incl. the use of ADAS).

Future directions for driver training and testing with automated driving

Contrary to general thoughts, automated driving may not necessarily make the whole driving task easier. Already the use of lower levels of vehicle automation (Level 1+2) results in additional tasks and responsibilities of a driver. This change is also being acknowledged by the current work under UNECE WP.29 for developing a UN Regulation on automated vehicles [22]. Examples of new driver tasks for Level 1+2 systems include:

- Determine when activation or deactivation of assistance system is appropriate
- Monitor the driving environment, execute parts of the driving tasks not being conducted by the system and respond if necessary
- Supervise the dynamic driving task executed by the system, be mentally engaged and intervene when required by the environment or by the system

The fact that the assessment of a learner driver indeed changes when vehicle automation is being used, was recently confirmed in the Dutch Prautocol project. This project aims at providing a good and solid starting point for certification and testing facilities around the use case Highway Driving. The two work packages 1b and 2 focus on licensing the driver by developing and evaluating tools to support the assessment of drivers of automated vehicles (Level 1-3).

One of the sub-tasks is to identify behavioural and knowledge aspects that are required for learner

drivers to supervise system control functions, starting with ACC and expanding to more advanced automated driving systems. The existing assessment matrix for driving examination in the Netherlands was taken as a starting point for making a step-wise comparison of required driver's skills for manually vs. system-controlled operation of automated vehicles.

Important preliminary results include the following:

- ADAS causes interruptions in task levels required from the driver. While activated ADAS mostly reduces the required task level for the driver, it now and then raises the required task level above levels that would be necessary if driving without system assistance.
- The criterion for adequate execution of the supervisory role is essentially: Does the learner driver remain in control of the assistance system? Based on the collected relevant aspects for the assessment of the driver's role during system supervision, the assessment of this role comes down to the appraisal whether the learner driver is capable of switching between the required tasks levels.
- For practical reason the appraisal of required competencies in system-supervision focussed at first on highway cruising with ACC. Since the identified relevant competencies were derived from generic descriptions of the driving task and overall recommendations for driving competency, the results seem to justify their validity of required competencies for supervision of ADAS in general (not only ACC). However to strengthen this claim the step-wise appraisal will in near future be applied to other systems as well, like Lane Keeping Assist and combinations. It also needs to be expanded for use cases other than highway cruising, like city driving.

More information can be found in the paper for this congress titled "Does the learner driver remain in control of assistance systems?" (Paper number ITS-SP1795).

The authors deem it of utmost importance to address in future driver training and testing the anticipated differences in the use and operation of automated vehicles (already from Level 1 onwards) from conventional vehicles that the public knows and operates today. Drivers should be provided the necessary level of understanding to use these technologies properly, efficiently and in the safest manner possible, based on knowledge and hands-on experience on what a system is capable and not capable of in order to minimize potential risks from system abuse or misunderstanding. Therefore the following policy considerations are being proposed:

- Add the use of vehicle automation (esp. current Level 1+2 systems) in driver training and make it a standard component in theory and driving tests.
- Make specific safety features mandatory in vehicles used for driver training and testing (e.g. hereby following the proposed EU regulation).
- Add the topic of vehicle automation to the education programs of driving instructors and examiners.

Conclusions

Future traffic will increasingly consist of mixed traffic, i.e. a combination of vehicles with various degrees of automation and vehicles without any of those features in addition to pedestrians and cyclists. This will affect the way vehicles are driven and the way road users behave in traffic. These developments raise the need to review and adapt current driver training and testing procedures to increase the users' ability to correctly work with automated driving systems and be aware of their potential and limitations in order to take full advantage of them.

For obvious reasons, current research and legislative efforts focus very much on automation level 3 and onwards (e.g. driver's involvement in dynamic driving task especially in case of transition of control, separate driving licence for automated vehicles). Since lower-level automation systems still require a great deal of human judgment and skill to operate safely, it is generally assumed that the current licensing and training procedures are still sufficient (i.e. human drivers still need to know how to manually control their vehicle).

However, what is being overlooked is that also lower-level systems significantly change the driver tasks. People should be made aware of which safety features their (current, new, rental) vehicle is equipped with, how to use these systems and what capabilities and limitations of the systems are to be expected. With European legislation encouraging and mandating the equipment and use of safety features, this ever more stresses the need to adapt current driver training and testing practices to account for technical developments and guarantee a safe operation of all levels of vehicle automation.

References

1. PRAUTOCOL (2018) WP2 Licensing the Driver, Task 1: Literature Review (internal document)
2. Kyriadis et al. (2015) A human factors perspective on automated driving, Theoretical Issues in Ergonomics Science, DOI: 10.1080/1463922X.2017.1293187
3. FERSI (2018) Safety through automation? Ensuring that automated and connected driving contribute to a safer transportation system, Position Paper
4. Connecting Mobility (2017) ADAS: from owner to user - Insights in the conditions for a breakthrough of Advanced Driver Assistance Systems
5. Klauer et al. (2018) Driver Training for Automated Vehicle Technology, Presentation at the Automated Vehicles Symposium, 9-12 July 2018, San Francisco, USA
6. ERTRAC (2017) Automated Driving Roadmap, Version 7.0
7. Bastian et al. (1998) Autonomous Cruise Control: A First Step Towards Automated Driving, SAE Technical Paper 981942

8. Motor & Equipment Manufacturers Association (MEMA) & Boston Consulting Group (BCG) (2015) A Roadmap to Safer Driving through Advanced Driver Assistance Systems
9. Future Market Insights (2018) Advanced Driver Assistance Systems (ADAS) Testing Equipment Market: Manufacturers to Focus on Providing Testing Equipment to Training Institutes and Third Party Service Providers: Global Industry Analysis (2013-2017) and Opportunity Assessment (2018-2028)
10. Walker (2018) The Self-Driving Car Timeline – Predictions from the Top 11 Global Automakers, https://emerj.com/ai-adoption-timelines/self-driving-car-timeline-themselves-top-11-automakers/ (visited 10 January 2019)
11. European Commission (2018) EUROPE ON THE MOVE, Sustainable Mobility for Europe: safe, connected, and clean, COM(2018) 293 incl. Annexes
12. USDOT (2016) Federal Automated Vehicles Policy, Accelerating the Next Revolution In Roadway Safety
13. Boudette (2018) Fatal Tesla Crash Raises New Questions About Autopilot System, The New York Times, https://www.nytimes.com/2018/03/31/business/tesla-crash-autopilot-musk.html (visited 24 April 2018)
14. NHTSA (2017) Automated Driving Systems 2.0, A Vision for Safety, USDOT
15. Hyatt (2018) Public interest groups urge Congress to change AV START Act, CNET Magazine, https://www.cnet.com/roadshow/news/public-wants-changes-av-start-act-congress/ (visited 26 April 2018)
16. European Commission (2017) The implementation of Directive 2006/126/EC on driving licences
17. European Commission (2017) Study on driver training, testing and medical fitness
18. CBR (2013) Rijprocedure B, Uitgave 2013
19. PRAUTOCOL (2018) WP1b Tools for licensing a driver as supervisor of driving automation, Task 1: Literature Review (internal document)
20. PWC (2018) Eerste vijfjaarlijkse evaluatie CBR, 16 May 2018
21. Vlakveld & Wesseling (2018) ADAS in het rijexamen, Vragenlijstonderzoek onder rijschoolhouders en rijexaminatoren naar moderne rijtaakondersteunende systemen in de rijopleiding en het rijexamen voor rijbewijs B, report no. R-2018-20
22. UNECE (2018) Reference document with definitions of Automated Driving under WP.29 and the General Principles for developing a UN Regulation on automated vehicles, 23 April 2018