European Commission

Study on the effects of automation on road user behaviour and performance

Executive summary

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EXECUTIVE SUMMARY

The study aims to provide the European Commission and other public authorities insights into the effects that the deployment of driver assistance, partial and full automation might have on road safety. The study investigates the implications of this deployment for EU policy and legislation. The specific objective is to identify and recommend those actions that need to be implemented in order to address the likely consequences, particularly adaptations of current EU and national legal frameworks for traffic rules, driving licences and the training of professional drivers that would be required as a result. The issues, main stakeholders involved and actions needed for the elaboration of a code of conduct for the transition to automated mobility are also considered. The topics covered concern highly specialised areas of automotive technology and transport regulatory systems. Despite the disparate topics covered these are an integral part of a regulatory infrastructure that ensure the safety of traffic and roads in Europe. The study started with a review of the current available literature on the topics of automation in general, the interaction of road users with automation, traffic rules, licensing and the training of professional drivers. This literature review turned out not to be conclusive, and a number of gaps were identified, which were subsequently the topic of an expert consultation carried out by means of thematic workshops and a survey. The results of the survey and our own findings were validated in two different workshops with invited stakeholders from the relevant fields. These validated results formed the basis for our practical and actionable recommendations.

State of the art

A new era is arising, with partially and fully automated vehicles (AVs) equipped with automated driver systems. Although automated driving has been tested on public roads in a few test areas, the literature review revealed that there are still large gaps where there is a need for more information relevant to policymaking. The transition to automated driving will affect the behaviour and performance of the driver and will influence the way in which road users interact with each other. This transition raises questions about policies related to traffic rules, infrastructure requirements, and curricula for licensing drivers. Research and expert consultations are needed to fill these gaps and to provide insights into the impact of automated driving on traffic safety, along with the harmonisation of the human-machine interface (HMI), legislation and driver training. Original equipment manufacturers (OEMs) are developing automated driver systems (ADS), and pilot experiments are being rolled out in many nations for testing automated vehicles at the Society of Automotive Engineers (SAE) levels 3 to 4. The technology of automated driving goes hand-in-hand with other evolving technologies, such as cooperative intelligent transportation systems (C-ITS) that allow communication between vehicles and between vehicle and infrastructure. The introduction of automated driving guided by policies that facilitate harmonisation can improve road safety.

HMI

In today's vehicles, drivers are used to gathering information about the vehicle's functions and their status from an on-board HMI. For this, the driver usually uses visual information from the display and auditory information from the various auditory alerts. However, the introduction of ADS raises questions about the complexity and importance of the HMI and the need for suitable interaction strategies. With ADS, the role of the driver changes significantly because the ADS can take over partial or even full control of the vehicle. The fact that different functional modes are available in one and the same vehicle makes a comprehensive and efficient interaction strategy very important. Depending on the role of

the driver, different information is needed to complete the requested task. The HMI needs to be designed to be adaptable in order to provide the user with optimum support. Additionally, the design of an ADS HMI needs to take earlier research into account. One of the most important tasks is the avoidance of known operator errors, such as mode confusion, automation surprises and overreliance. Since most operator errors are a result of insufficient or inadequate information, it is important for the HMI to deliver information regarding the underlying functional logic of the ADS, the handling of the new control elements and current information provided by the ADS system. Therefore, it is recommended that the "commonality" of an on-board HMI be promoted. This includes the functional logic of ADS, the control elements and the information presented across vehicle types and manufacturers. Further, there needs to be agreement regarding the minimum requirements for the information to be presented to the driver in order to promote user understanding and trust.

External human-machine interface (e-HMI)
Our study on integrating AVs into traffic examined the need for specific communication between AVs and other road users – human drivers, pedestrians, cyclists and motorcyclists. The process started with a literature review, which revealed that most of the experimental studies had focused on the interaction of automated vehicles (AVs) with pedestrians. There were substantial shortcomings in those studies and in many of the communication solutions that were proposed. The next stage of this study was a within-project expert discussion, which identified a set of initial conclusions and recommendations. The conclusions were supported in an interactive stakeholder workshop but received less support in an on-line questionnaire. The overall recommendation is that AVs should use the existing e-HMI that is found on current vehicles (indicators, brake lights, horn, etc.) because new and different solutions could cause confusion when road users have to interact with multiple vehicles, both conventional and automated. A signal light to indicate that a vehicle is being driven by an automated driving system is advocated, as are some specific solutions to address specific needs.

Traffic Rules
In order to ensure the safety of all road users and undisrupted traffic with the deployment of automation, traffic rules and provisions might need to be added or adapted. The consequences of the expected deployment of automation are assessed discussed, using the current general traffic rules in Europe as baseline, and taking into account an increasing penetration rate of automated vehicles. The literature shows that automated driving has not yet resulted in much of a change in current traffic rules. There is one accepted amendment to the Vienna Convention (UNECE, 1968): Article 8 states that "Every moving vehicle shall have a driver" and "Every driver shall at all times be able to control his vehicle or to guide his animals." The amendment now recognises that an automated driving system can be the "driver" and that the driver therefore does not have to be human.

In general it is concluded that the traffic rules for automated vehicles do not necessarily need to be different from existing traffic rules. The main recommendation is that current traffic rules need to be translated into exact and measurable rules that can be programmable for ADS (sometimes also called the "digital traffic act"). Local variations in traffic rules and variations between Member States should be included in the digital traffic act. In this way, an ADS can switch to specific regulations when crossing a border, comparable to switching digital maps for a navigation system. This digital traffic act should indicate how to deviate from the rules in emergency situations. Also, during automated

driving, non-driving-related activities that are currently not permitted might be allowed. This depends on the automation level and the type of the activity.

Driver licensing

Whilst there is a harmonised approach to driver licensing in the EU Member States, there is a wide variety of approaches to driver training and testing. Thus, the training of new skills, where identified to be of importance for the safe operation of AVs, would be nationally devolved. However, through consultations with stakeholders, this study has identified a number of suggestions or concerns with regard to the updating of licensing procedures. Drivers have been expected to use Level 1 and 2 automation without specific changes in licensing and training procedures; however, studies have indicated that drivers are not always knowledgeable about the Level 3 or 4 automation functionalities present on their vehicles. In order to reap the benefits of AVs, drivers should be familiar with the purpose of the automation, particularly their role and responsibilities in interacting with it. With regard to drivers yet to obtain their licence, they could theoretically be given the choice of being trained to drive either a standard vehicle or one with autonomous features (or both).

The subsequent testing and licensing of those drivers could also be adapted to lead to newly qualified drivers holding different types of licences that would restrict their driving to certain types of vehicles. However, the timely legislation and enforcement of such an approach could prove to be insurmountable, and given the rapidity of technological advances, such an approach might not be agile enough to cope with changes. The stakeholder consultation indicated that drivers could glean the requisite skills and knowledge via an interactive in-vehicle coaching tool, over and above what is provided by a typical owner's manual, and implemented on hired or shared vehicles for drivers to access. Further discussion with vehicle manufacturers is required in order to understand the limitations and barriers of implementing this. Not losing "manual" driving skills after an extended period of driving an AV is an additional concern, and the in-vehicle coaching approach could be adapted to help mitigate this. Research in virtual-reality environments is needed as a way of developing knowledge for training new skills. The relaxation of regulations around fitness to drive should be considered as a possibility, except in Level 5 vehicles.

Professional training

Directives 2003/59/EC and 2018/645 provide the framework for the harmonisation of EU professional driver training and the certification of professional competence, which requires periodic training every five years. This legislation improves harmonisation of driver training in the EU to a great extent, but still leaves room for Member States to organise professional driver training differently. In light of automation, the mandatory periodic training, along with the topic of automation prescribed in Directive 2018/645 provide all necessary handles to acquire new knowledge and competence on evolving technologies such as ADS and advanced driver-assistance systems (ADAS).

To provide suggestions on any new knowledge and competence that automation will bring forward, a general overview of the professional environment is outlined, including road safety. This is an important factor in sorting out new knowledge and competence, because the principal aim of driver training is to improve road safety. Automation is a topic that can be covered in the theoretical part of the training in fulfilment of the legislative objective involving the technical characteristics of the safety features to control the vehicle and

execute pre-drive checks. Training should allow professional drivers to check their ADS or ADAS, and therefore, they should have a basic understanding of the main components involved in automated driving. While driving, drivers should know the correct operational status of the system and the procedures for interacting with it, including understanding the HMI and the information displayed. Operational competence is better covered by practical training. In the stakeholder consultation it was suggested that, whilst driver simulators can be helpful, especially for basic skills, higher-order skills are best trained on-road, with context and a proficient trainer. These topics are mainly related to driving or monitoring the vehicle, but some topics are not directly linked to the task of driving. One of these is liability. Although it is still an open issue in automated driving, professional drivers should learn about liability as it relates to automation, since their vehicle might carry heavy cargo or many passengers and would result in more damage in case of accident.

Towards a code of conduct to the transition to automated mobility

In this chapter, we discuss insights into the issues that might arise and their likely effects on the behaviour of road users, the changes needed in traffic rules, driver licensing and the training of professional drivers. These insights are reflected in a list of actionable topics aimed at developing a road map to guide the transition to automated driving. Key stakeholders in the implementation of these actions are the European Commission, OEMs, the road authorities in Member States, United Nations Economic Commission for Europe (UNECE), etc. Regarding the time horizon for an implementation roadmap, most actions are related to concerns about automation Level 3 and, in some cases, Level 4. There was agreement among the experts consulted that most of the actions required could be accomplished in the course of three years, with some exceptions for automation Level 4, which is expected to take up to 10 years to be accomplished. The elaboration of the code of conduct would require addressing at least four domains of moral hazard that might arise. The first domain concerns the general principle of safety and autonomy of road users. The second refers to the shift in responsibilities and liability from the driver to other entities. The third concerns the security, safety and privacy of the data flowing between the car and the user. The last points out issues that the drafters of the code of conduct will face while aiming to guide innovation and the behaviour of diverse stakeholders through the transition to automated mobility.

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