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A Note on Accidents Involving Autonomous Vehicles: Interdependence of Event Data Recorder, Human-Vehicle Cooperation and Legal Aspects

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Abstract: Following the increase of automation levels in personal and public vehicles in the last decades, this note aims to discuss interdisciplinary investigation required to address criminal liability in case of an accident involving autonomous vehicles. Lawyers need from technicians definitions of automation levels. Each automation level requests differently the driver generating the need for related psychological and ergonomics studies. Finally, in the case of an accident, an Event Data Recorder (EDR) is of vital importance to reconstruct the events to the lawyers.

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Keywords: autonomous vehicles, human-vehicle cooperation, human operator, temporal frame, risks, penal responsibility, cyber-physical system.

1. INTRODUCTION

Criminal responsibility in the case of accidents involving autonomous vehicles is an actual open and very complex topicⁱ. This note does not aim to give a solution, even because it can vary from one country to another, but to analyze and discuss the topic also putting in evidence the need for cross studies.

We also discuss in this note the Vienna Convention on traffic regulationⁱⁱ and its recent 2016 amendment as well as the propositions being analyzed by WP.1ⁱⁱⁱ of UNECE with regard to different parameters, as for example the recovering time. Indeed, the amendment in the Vienna Convention has been effectuated after peer analysis of human-vehicle cooperation issues. Finally, Event Data Recorder (EDR) is studied in relation to the law and to technical challenges associated.

2. AUTOMATION LEVELS, TEMPORAL FRAMES AND HUMAN-MACHINE COOPERATION

Systems with higher levels of automation, and then more intrusive in the humans' tasks, have been object of many studies in the last decades (Hoc et al. (2009)). The level of the system intrusion with respect to the human has also been studied in (Scholliers et al. (2008, 2011)) as being associated to the usage for which the system is designed (in the context of driving assistance systems). In a risky situation, it is also associated to the temporal frame of the risk - e.g. a vehicle on an icy road can certainly generate risks with such a few time to recover a safe state, that we have an obvious evidence of the need for an automated corrective system (instead of only an alarm). Different technological challenges in terms of sensors, and their range and precision, are also involved in each case (Scholliers et al. (2008, 2011)). In addition, the hierarchical structure of the driver performance, Michon (1985), structured at three levels, is related to three different temporal frames

(long time constants, seconds, milliseconds), in Figure 1. These intrusion levels of the machine with respect of the operator have also called for the definition of modes of cooperation between the machine and the human (Hoc et al. (2009)). More recently, four classes of interaction of the cyber-physical system with the human have been defined (H-CPS-I (2014), Netto & Spurgeon (2017) & Lamnabhi-Lagarigue et al. (2017)), as follows:

- Class CPHS 1: Human-machine symbiosis;
- Class CPHS 2: Humans as (a) operators, or (b) supervisors of complex engineering systems;
- Class CPHS 3: Humans as multi-agent systems; and
- Class CPHS 4: Humans as agents in controlled systems.

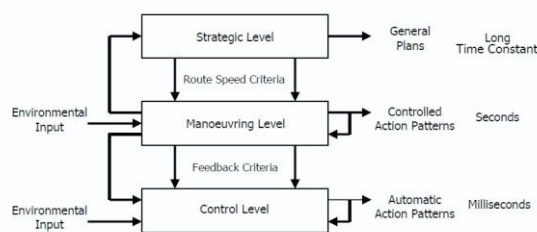


Figure 1: The hierarchical structure of the driver task (from Michon (1985)).

In terms of technical definitions, the Limited Operational Design Domain (ODD) describes how an automated vehicle is capable to drive given certain conditions. This definition may contribute, as discussed further on the text, to set who is responsible for what in the accountability process.

Vehicles equipped with Automated Driving Systems (ADS) levels 3 and 4 (SAE J3016 (2016)) are capable to perform intelligent actions without human intervention, but they still maintain the human driver as a supervisor or operator (CPHS2b). So, in case the ADS reaches its internal limit or when it detects that an electronic fault or failure condition has occurred, the system shall start a fallback procedure to handle

a situation outside the ODD, asking the human (operator or supervisor) to regain full control of the driving situation.

The revised report (2016, 2018) of the SAE automation levels also known as standard J3016TM^{iv} (SAE J3016 (2016)) indicates the minimum system capabilities for each level, pointing where the automated driving system performs partially or completely the dynamic driving task. This taxonomy can be used as a non-binding document by authorities in case of road accident. The use of the EDR (black box) is discussed in relation to legal aspects in the next session.

3. EVENT DATA RECORDER

Since accidents may happen under various circumstances, a mandatory inclusion of EDR aboard automated vehicles seems required to discriminate human driver negligence from non-adapted or incorrect product design or a product defect or fault (Bose (2015), Kohler & Colbert-Taylor (2015)).

The difficulty to separate a manufacturer's fault from a driver's fault lies in the difficulty of evaluating the cause of an accident. Because of that, the NHTSA^v calls for the industry to work with IEEE and other standards bodies to develop a uniform approach to address data recording and sharing [NHTSA, 2016^{vi}, ^{vii}, 2017^{viii}]. We could indeed classify the possible accidents within three different causes:

- 1) Negligence of the driver/supervisor/operator;
- 2) Inappropriate system design (that may lead to an inappropriate behavior of the automated vehicle); and
- 3) Fault in the system (a sensor that stops functioning, or in a higher level, an obstacle non-correctly identified).

Case 3 is related to the verification step in the V-Cycle (Scholliers et al. (2008)) and case 2 to the validation step - and then to a possibly incorrect specification of the function (for example, a too short time for the driver to recover the control of the vehicle). Finally, only negligence (case 1) could be considered as responsibility of the driver and here legal studies connect clearly in our opinion to human-cooperation studies: how to qualify negligence considering SAE level 3 vehicles (SAE J3016 (2016))? The "time" parameter seems to us the key for this connection: only by giving sufficiently long safe time to the fallback, one could qualify a non-response of human driver as negligence. This analysis links the design levels of the system (components level, algorithms level, function levels) with the possible errors (technical errors, errors in the design of the system) to also allow classifying a possible negligence of the driver.

One could use this analysis to come back to recommendations in the systems design: how to distinguish negligence from the other two situations? Certainly negligence could not be characterized if time to response is not enough to a reasonable person. So, regulatory framework should imperatively include as a parameter, "appropriate time". If so, those technological innovations may serve governments to achieve Conventions on the road traffic, for a safer traffic.

EDR devices are actually able to obtain untreated data from the vehicle (speed, acceleration, engine temperature, etc.) and its environment (camera images, temperature, air pressure,

etc.). They cannot collect treated information provided by the perception, localization, local and global navigation, and control systems. In this sense, a new concept of data recording device, aiming to support technical expertise for investigation and resolution of failures has been proposed in Barbosa et al. (2016). However, the visualization of the scenario recorded can be hampered by the complexity of the data and by the absence of a storage pattern. In this way, Grego (2018) discusses the data recording devices in a step further in an effort to obtain a standard of data storage. Preliminary results point to a storage pattern that will be useful in the development of a visual reconstruction system as an aid to technical expertise. Currently, different entities discuss the need for standardization of nomenclatures, security controls, mode of operation of the ODD and Object and Event Detection and Response (OEDR). There are still issues related to data ownership and sharing. An international standardization of storage procedures should still be obtained to ensure compatibility of registration or documentation obligations [NHTSA, 2016, 2017; please, see the following reports: Parliament of the Commonwealth of Australia, 2017^{ix}; Federal Ministry of Transport and Digital Infrastructure, Germany, 2017^x; H.R.3388 – Self Drive Act, US, 2017^{xi}].

The use of data stored in their EDRs in the courtroom may be subject to judicial scrutiny, depending on the legal system, directly connected to case 2 above. On the other hand, what if there is nothing to use, for example, in case innocuous questions are posed to experts? Prosecution office should be prepared for challenges related to that use before criminal courts. Responses provided by experts should clarify how responsibilities can be shared between vehicle owner, driver, supervisor, transport operator, automotive industry, manufacturer of the ADS, in particular, if it happens during the transition period when human driver is supposed to retake the control of the driving task (please see Melquiond & Guilbot (2017) that discusses the penal responsibility of other bodies indirectly involved in a road accident in normal driving; and Buiteweg et al. (2018) that presents a draft with definitions for each element in the automated (SAE level 3 or plus) context).

CPHS issues related to traffic accidents scenarios are discussed in relation to legal aspects in the next session.

4. AUTOMATION LEVELS, HUMAN-MACHINE COOPERATION AND CRIMINAL RESPONSIBILITY ARISING FROM ACCIDENTS

Taking into account the technical evolution from ADAS to highly automated vehicles, thought has to be given to how the traffic conventions have to be updated to fit those systems and give them legal certainty. Because as Westbrook^{xii} says, "*no other technology exists that can break the law without the input of the human operator, and AVs have the potential to do just that*". Dispositions from international treaties (Geneva, 1949^{xiii}; Vienna, 1968^{xiv}) assume that there is a human driver physically and mentally capable to drive and that he/she occupies the driver's position inside the vehicle. However, as long as ADS have come to maturity, human drivers are now capable to drive from outside, but close to the vehicle (e.g. self-parking remote controlled^{xv}), as well as outside and far

from the vehicle (e.g. a central monitoring room^{xvi}). None of these treaties and its updates has the potential to push the responsibility of the human driver away in case of a road accident.

Considered as a supervisor of an ADS level 3 SAE (class CPHS 2b and also related to class CPHS 3), the human driver in the pilot's seat has nothing to do but monitoring the vehicle's environment. Feron (2016) shows that this monitoring activity can lead to a swing of the cognitive state between two extreme situations - either the driver loses concentration or it is possible that he/she will be overloaded by data coming from different sensors and he/she might not understand what is needed (for more information, please see the Air France Flight 447 crash analysis, Harford (2016)).

In the past few years, human factors researchers have been increasingly concerned with the effect of different forms of training on performance and safety related to the use of highly ADS, Payre (2015), Cunningham & Regan (2018). From a criminal liability perspective arising from accidents, results are not encouraging as long as a sufficient response time (with different results in the literature, from 7 to 24 seconds, as in Eriksson & Stanton (2017), Louw & Merat (2017), is necessary to gather proper situational awareness so drivers make the right decisions and perform them properly.

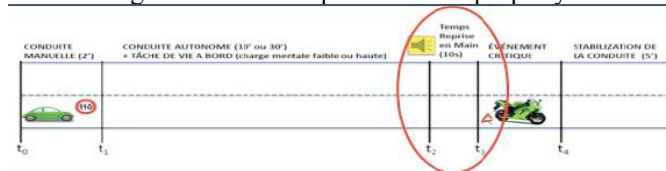


Figure 2. The figure shows a road accident during the transition time (between t2 and t3) after 10 minutes (between t1 and t2) of automated driving. Source: Mercedes Bueno Garcia, Human factors Research, VEDECOM, 2015.

Road safety is managed by the principle of personal responsibility of the driver. The problem raised by the criminal law systems arises from the fact that it is not satisfactory to base the offense's liability on the human driver when an ADS system is activated. In this perspective, who will be held liable instead of the driver when a driving offense is found while ADS is active? In the Brazilian jurisdiction, by virtue of the principle of the individual nature of penalties (art. 5°, XLVI, CF/88^{xvii}), the principle of legality (art. 5°, II, CF/88) and the general principle of presumption of innocence (art. 5°, LVII, CF/88), according to which is responsible the person designated by the offense, the recognition of a person other than the driver (or the holder of the registration certificate) may only be modified by legislative means, that is to say by a modification of the criminal texts.

In fact, operating a car is not the same as supervising the ADS (Schellekens (2015)), while control is not just grabbing the wheel^{xviii}. Because decisions are performed in an increasingly way by algorithms, people get passive and less vigilant and human drivers become more dependent on the systems, creating a vicious cycle (Eriksson & Stanton (2017)). Accountability in this perspective should consider interpretation of the traffic law by software, the balance between obeying traffic rules and incorrect or inadvertent maneuvers to avoid accidents (wrong doing regarding to traffic rules), how to take into account interactions in mixed traffic

(automated and non-automated driving) and who will be responsible to training the human driver as long as to him, a driver license is mandatory?

With this scenario, the introduction of level 3 SAE vehicles (SAE J3016 (2016)) may not lead to the desired result as envisaged in both 1949 and 1968 Conventions on Road Traffic. For society at large, road accidents (due to the time human driver needs to retake the control of the vehicle in order to avoid an accident) or traffic accidents (due to an unreliable interaction between human and system) can prevent the societal confidence on the technology (Lenz & Fraedrich (2016)) and thus be a negative factor for a commercial phase of AVs. After all, it is not difficult to understand how people may quickly lose confidence in algorithmic after seeing them make the same mistake (Dietvorst et al. (2014)), especially when a party other than the ADS or its developer can be condemned to the payment of a heavy fine in compensation for damages resulting from infractions of the Traffic Code, or sentenced for manslaughter in traffic (art. 302, Brazilian Traffic Code^{xix}).

Understanding how to respond to transition situation of the vehicle's control, how to interpret new displays and the necessity of recurrent training to keep drivers up to date with technical evolution is a concern to road traffic authorities (Valmain (2017a, 2017b)) and also to manufacturers worldwide. Actually, during the Workshop on Governance of Automated Vehicles (ONU, Geneva, 2017^{xx}), experts from the U.N. World Forum for Road Traffic Safety (WP.1) and World Forum for Harmonization (WP.29) showed great concern in driver's distraction issues including which other activities would be permitted to human drivers during automated driving SAE level 3. It is important to note that synergies action between 'technical' groups and others (researchers, automotive industry, representatives of different ministries [Transport, Justice, Health, Education, Economy, Home Affairs], but also representatives of associations and private companies) provided the interdisciplinary competences that have been needed to the amendment of the Vienna Convention on Road Traffic (1968) in March 2016. Technologies transferring driving tasks to the vehicle have been henceforth allowed provided that these technologies were in conformity with the U.N. vehicles regulations (under the responsibility of the WP.29) or if they can be overridden or switched off by the driver (art. 8, paragraph 5bis).

With this in mind, the need for an interdisciplinary approach to understand criminal law issues involving SAE level 3 of automation (SAE J3016 (2016)) becomes apparent. The out-of-the-loop phenomenon and its effect on driver behavior during the transition from automated to manual control (Louw (2017)) is one of the most significant challenges related to the criminal liability in case of a road accident during the takeover time. And it is true that the accountability, which was previously individual (driver or owner) might shift to manufacturers and/or operators of ADS. Lawmakers are facing the difficult task to protect both the public (including precautions to prevent the loss, misuse or alteration of user's personal data stored in the EDR, Vingiano-Viricel (2017) and Guilbot et al. (2016) and the industry, while revising the law,

Sheriff (2017), to accommodate all the changes and provide clarity for additional deployment and certainty in the investment in autonomous vehicles, Hamilton (2017). Even though a recent study has presented a formal and mathematical model to ensure that ADS functions properly and then manufactures could not be held liable, Shalev-Shwartz et al. (2017), there are errors, imperfections and uncertainties that could not be mapped previously.

5. CONCLUSIONS

The vehicular automation is a major milestone on the roadmap for terrestrial mobility in the forthcoming years. If the straight target is to progress the road transportation safety, its implementation is complex and involves different technological, regulation and human aspects. In order to draw a global picture of this issue, a multidisciplinary approach is required. Here, we have discussed a few topics that seem mandatory to be considered in order to establish responsibilities in autonomous vehicles accidents, that are starting and tend to inflate in the next coming years.

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