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The concept of activities other than driving

Submitted by Human Factors in International Regulations for Automated Driving Systems (HF-IRADS)

This document, submitted by HF-IRADS, is a position paper on driver responsibility with automation titled "Can the human driver be made responsible when automation is unable to handle the situation?". WP.1 is invited to discuss it.

Can the human driver be made responsible when automation is unable to handle the situation?

A Position Paper from HF-IRADS[1]

Introduction

As long as automation requires human intervention, a safe and effective approach is needed for how and when the control of the vehicle can be transferred. The approach depends on the level of automation. There are different levels of automation (see, e.g., SAE, 2019)[2] but they can be broken down into two main levels: Advanced Driving Assistance Systems (ADASs, SAE L1 and L2) and Automated Driving Systems (ADSs, SAE L3-L5), with ADSs having more capabilities then ADASs. Moreover, ADASs support the driver but the driver remains responsible for the driving task.[3] In this paper when we refer to ADASs we refer to SAE L2 automation. Since automation is progressing (also with ADASs) the question how and when the control of the vehicle can be transferred to the driver becomes highly relevant. In this position paper, HF-IRADS will provide some insight into what is reasonable to expect of the human driver. This discussion is framed around a series of questions.

Can the driver be expected to "immediately" take over control of the vehicle if requested by the ADAS/ADS?

The issue of whether a driver can be expected to 'immediately' take over control of the vehicle already arises from driving with an ADAS. With ADAS, the driver has general responsibility for the safe operation of the vehicle and is supposed to take over control at any moment if needed. In other words "The system can relinquish control with no advance warning and the driver must be ready to control the vehicle safely." (NHTSA, 2013, p. 5). The driver also needs to be aware of system limitations, for example the inability of an ACC to handle some cut-ins by another vehicle. However, since longitudinal and lateral control can be performed by the ADAS the driver can be "... disengaged from physically operating the vehicle by having his or her hands off the steering wheel AND foot off pedal at the same time." (NHTSA, p. 5). In a vehicle equipped with ADAS, which is capable of longitudinal and lateral control, the driver can become an 'operator', that is, a supervisor who is supposed to monitor the operation of the system(s) and the environment. This is necessary because ADASs can't handle many safety-critical situations.

With respect to drivers as 'operators', the Dutch Safety Board (2019, pp. 38–39) wrote "Monitoring the driving process in the role of operator, as is the case when driving with ACC in combination with LKA, involves risks that do not affect conventional vehicles with active drivers. This is because operators have longer response times than active drivers (more than six seconds in some cases in comparison to about two seconds for active drivers) and they also miss more information. Operators are also likely to be more easily distracted and less alert than active drivers."

[1] "Human Factors in International Regulations for Automated Driving Systems" (HF-IRADS) operates under the auspices of the International Ergonomics Association (IEA). It brings together human factors experts from across the world to support UNECE activities on the safety of automated driving systems.

[2] There are different definitions for the levels of automation. The definitions of SAE are the ones mostly referred to.

[3] It is important to point out that although with ADASs words such as 'support' and 'assist' are used, ADASs can take over control of the longitudinal and lateral part of the driving task. In that sense the distinction between an ADAS and an ADS might difficult for a driver to understand.

Although one can state that it is the legal responsibility of the driver to take over control anytime with ADAS, it is unreasonable to expect that the driver can take back immediate control of the vehicle. The mere fact that specific parts of the driving tasks are taken over by the ADAS results in longer response times for operators than for 'active' drivers. 'Hands off the steering wheel and foot off the pedal' usually result in longer reaction times than hands on the steering wheel, foot on the pedal, and eyes on the road. Well-designed (combination of) ADASs will take reasons for longer reactions times into account (see also Pipkorn et al., 2021).

An Automated Driving System (ADS) is far more capable than an ADAS. It can handle the entire longitudinal and lateral driving task including safety-critical situations (e.g., emergency braking). It can perform these tasks, however, within a limited Operational Design Domain (ODD; for example, it may function in dry weather conditions but not in rainy weather). Concerning ADS, NHTSA (2013; p. 5) states: "The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The vehicle is designed to ensure safe operation during the automated driving mode…, providing the driver with an appropriate amount of transition time to safely regain manual control." An ADS should be capable of recognising situations that are outside the ODD, and of conveying this to the driver in a timely manner to ensure that the driver has sufficient time to assess the situation and regain control of the vehicle. An ADS provides room for the driver to perform 'non-driving related activities' (NDRA).[4] The driver becomes more like a passenger who, while the ADS performs the driving task, can perform other activities such as reading a book or emails. Some drivers may even need to switch glasses to do so. Therefore, with an ADS there should always be a transition process that provides a reasonable amount of time for the driver to cease their NDRA, to regain awareness of their surroundings and situation, and to regain control of the vehicle. Any sudden release of control by the ADS could result in abrupt steering by the human driver with the risk of loss of control or collision with a vehicle.

There is strong evidence that engagement in NDRA can lead to a longer takeover time (TOT) by the human driver and, depending on the type of activity, can also affect the quality of takeover (see e.g., http://www.unece.org/fileadmin/DAM/trans/doc/2018/wp1/ECE-TRANS-WP1-2018-INFORMAL-Sept-9e.pdf). Zhang et al. (2019) performed meta-analyses of the TOTs from 129 studies of SAE L2 systems (ADAS) and higher (ADS). Their results show that:

- "...a shorter mean take-over time is associated with a higher urgency of the situation, not using a handheld device, not performing a visual non-driving task, having experienced another take-over scenario before in the experiment, and receiving an auditory or vibrotactile take-over request as compared to a visual-only or no take-over request. A consistent effect of age was not observed." (p. 285).
- Also "... a high level of automation (SAE L3 and above) showed higher mean TOTs compared to partial automation (SAE L2)" (p. 298).

Zhang et al. (2019) also indicated limitations of their work and the studies they used. Among these are, for example, that the definition of TOT differs between studies and that many studies were performed by universities (thus based on young drivers) and using driving simulators. Another observation is that the focus in these studies is on how fast drivers can take back control of the vehicle. However, this provides no information about the quality of driving after taking back control. As Zhang et al. put it "...a short TOT does not necessarily indicate a safe situation." (p. 299).

[4] Which NDRAs could be allowed and what safeguards should be in place is a question that still needs to be answered for different levels of ADS.

Zhang et al. do give a clear answer to the question we are dealing with. A "...high level of automation (SAE L3 and above) showed higher mean TOTs compared to partial automation (SAE L2)". So it cannot be expected that a driver takes immediate control of the vehicle when the ADS performs the driving task.[5]

The ***transition process*** should not only focus on TOTs but also on control quality, regaining situational awareness, and how to verify both. A simple check whether the foot is back on the pedal and hands are back on the steering wheel is not sufficient. Furthermore, research has shown that when drivers had more time to regain control they prioritized NDRA above regaining immediate control of the vehicle. "When operators shift their priorities to non-driving tasks, their readiness to respond to driving-related prompts and alerts can be delayed by a perceived obligation to complete the non-driving task first." (see Blanco et al, 2015, p. 110). So the transition process requires a good balance between different aspects.

The ADS should be designed to *support* takeover as opposed to merely *demanding* takeover. An example of this would be assisting human drivers to recover situation awareness before resuming control. Interface design can, for example, assist in the recovery of situation awareness by providing strategic (where am I?) and tactical (what are the locations of the vehicles around me?), and operational (how fast am I driving?) information[6]. There may be a role for nudge or reward to encourage drivers to cease their NDRA.

With respect to the transition process, there is a situation that ADS should be able to deal with and that is the situation in which the driver does not take over. One can state in the user manual that the driver must be able to resume control of the vehicle within a 'sufficiently comfortable transition time' but it is reasonable to expect that drivers may fall asleep behind the wheel when the ADS is engaged. This can occur simply because of a lack of involvement in the driving task. Somehow this possibility must be addressed.

Can the driver be expected "immediately" to take over control of the vehicle upon critical system failures?

In the 1990s a series of rollover crashes caused fatalities and serious injuries to the occupants of Ford Explorer vehicles. The problem was identified as being caused by tread separation in the Firestone tyres fitted to the vehicles. A recall was eventually imposed by NHTSA on the relevant tyres. However the CEO of Firestone also stated: "When a driver of a vehicle has something happen such as a tread separation, they should be able to pull over not rollover." (CBS News, 8 August 2001). The same lesson can be applied to ADS: the system should be able to mitigate serious vehicle failures, and it should not be necessary for the human driver to intervene immediately to protect against an adverse outcome. Drivers engaged in NDRAs in a such a situation could be expected to have delayed responses, both because they may be slower to detect the problem and because they may have to cease physical interaction with the NDRA in order to act.

ADAS may stop functioning due to an internal failure without issuing a warning. The vehicle can, for example, collide with an object without a warning when detection of the object is beyond the functional capability of the system. We have already seen fatal crashes with ADAS (at SAE L2) where the ADAS failed to alert drivers that they could not handle the driving situation. ADAS can require the driver to detect an object/event, override the system and avoid the collision manually within a short time period. To promote initiation of driver intervention, understanding the functional limitations of the system is as important as appropriate monitoring of the surrounding environment. An appropriate mental model of the system is required for this understanding of the functional limitations of the system for promoting immediate

[5] The results of Zhang et al. (2019) also suggest that more automation with ADASs may lead to longer TOT.
[6] The three mentioned levels (strategic, tactical and operational) come from Michon (1985).

response actions. Education and training may be as important as a good HMI (see also Regan et al. (2020) on skills and training for driving with an ADS). To help drivers generate an appropriate mental model, the simplicity of the system functions is also important.

How should transitions to the driver be managed in terms of the dynamics of the transition?

Transition periods can be treated in terms of successive stages. At each stage, the ADS has responsibilities. It is only when stable control has been achieved by the human driver, that the ADS can be considered to be absolved of responsibility for maintaining safe driving. There are specific responsibilities relate to each stage.

Marberger et al. (2018) and ISO 21959 provide a useful diagram of the stages in the transition process in a system-initiated transition from automated to manual driving (see **Figure 1**). The diagram shows a series of necessary stages in the process and, most important of all, the process does not end when the driver reengages with the vehicle controls. Even this complex diagram is not complete in that it does not include the process of the driver recovering situation awareness of the road environment and the surrounding traffic at the tactical level of the driving task.

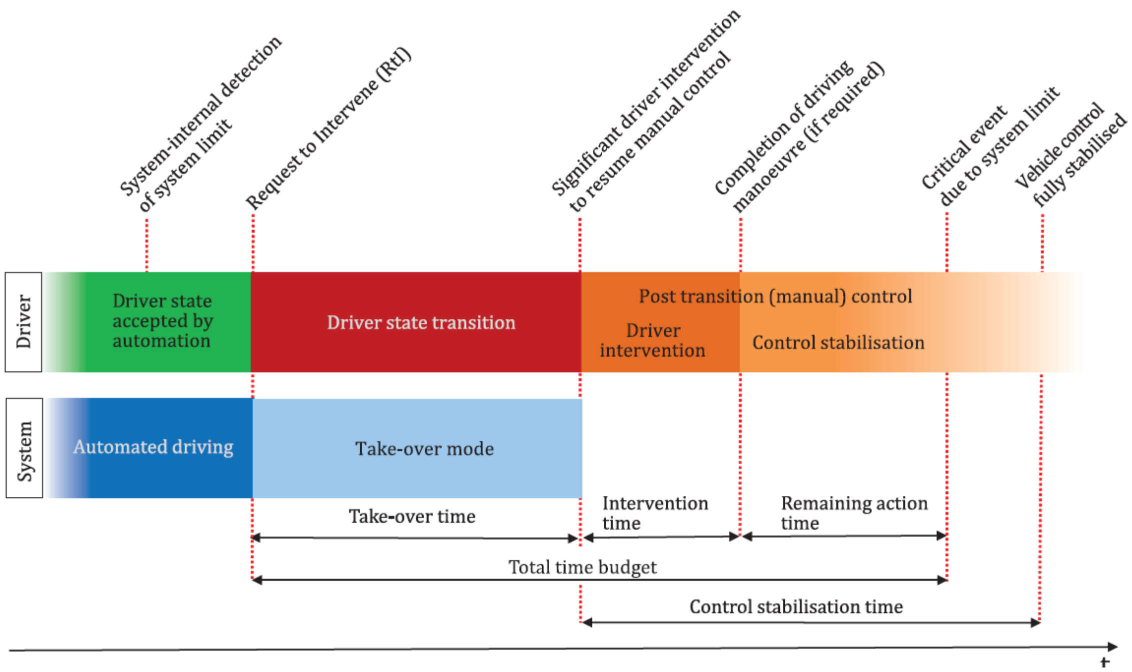

Figure 1: System initiated transition from automated to manual driving (Source: Marberger et al., 2018; ISO, 2020)

Can the driver be required to understand the functionality of an ADS and its limitations?

A complex set of terms and conditions and even specific warnings in an owner's manual are no substitute for intuitive designs and clear delineation of responsibilities. Drivers do not necessarily have access to an owner's manual, for example when using a rental car and tend only to consult the manual either when a problem occurs (e.g., a warning light comes on) or when they cannot figure out how to enable some feature or use some function.

So the inherent design of the ADS, and specifically of its interface of its interaction with the driver, should promote driver awareness, including when and why the ADS is reaching its performance limitations.

Furthermore, as with any complex system, users develop their understanding of system performance boundaries and limitations by experiencing system behaviour and interaction, as opposed to reading a set of instructions. Hard limitations to ADS performance should be avoided; graceful failure will support responsible intervention by drivers. However, not every user in every situation can be expected to take over in a timely and safe manner when requested. The Safe System approach to road safety (OECD, 2008; 2016) requires system providers to design systems with the expectation that user errors will occur. ,Thus the design of ADS should minimise the potential for user error, and should mitigate the consequences of inevitable error. As an example, there should be the provision of a fallback when there is a failure to respond to a takeover request, where the fallback does not impose unacceptable risks on the vehicle occupants or other road users.

This does not mean that drivers, when first having contact with an ADS, will be totally ignorant of the purpose and proper usage of an ADS. Public education and rules on, for example, when it is permitted to engage in non-driving related activities, will promote user awareness, just as they do for manual driving. Drivers need to be aware that the ADS will issue takeover requests and that they should respond appropriately to such requests, especially since a deliberate failure to respond may place the vehicle in a less safe condition.

Manufacturers should validate that their designs promote user understanding and proper usage. And authorities should require confirmation that such studies with representative drivers have been performed.

A clear distinction should be promoted between driving with ADAS on the one hand and ADS. ADAS systems can be described in terms of what they do not allow, including disengagement from the control and tactical aspects of the driving task. Likewise, ADS can be depicted in terms of what they do allow, i.e., attention diverted from the driving task, but also in terms of the expectation they will issue a request to intervene (take over driving).

The need to study human behaviour with automated driving systems in Field Operational Tests

Driver interactions with ADAS and ADS systems are complex and are at the moment mainly investigated in driving simulator research. Trials in driving simulators are extremely useful to investigate usability, initial trust, workload, understanding of system operation, and naïve users’ responses to emergency situations. They are one of the diverse methodologies available for investigate human factors aspects of driving behaviour. Another highly relevant methodology is Field Operational Tests (FOTs) in which the effects of ADASs/ADSs can be investigated under daily real-world driving conditions. An FOT is very well suited to look at complex behaviours such as learning and adaptation effects over time or at how the variety of real-world situations affects usage of the systems. Data from FOTs are also highly relevant for assessing the impact of the investigated systems on traffic safety, traffic efficiency and the environment. From this perspective, there is a real need to employ FOTs for longer-term investigations under naturalistic conditions with actual drivers so that learning effects and adaptation over time can be ascertained and the real impact of these systems can be assessed.

Conclusions and recommendations

When an ADS is operating the vehicle, the safety of driving is the responsibility of the manufacturer. It cannot be expected that the human driving in a vehicle with automated systems can take back control immediately and with "high quality". Humans can be encouraged to detect and respond to problems, but they cannot be held to be co-responsible, except in case of deliberate misuse. So ADS should be designed in the hope that humans will be responsible and responsive, but in the expectation that they will not. This imposes an onus on system designers and approvers to ensure that ADS fail gracefully and that the non-response of a human does not impose unacceptable risks on vehicle occupants or other road users. Minimum risk manoeuvres, that are performed safely and which place the vehicle in a safe situation, have to be provided. One mechanism to promote this responsibility of system providers, would be legal liability for failure to provide a robust ADS.

In the case of an ADAS, the driver is responsible for the safety of the driving task. Nevertheless, the expanding quality and the extension of the conditions in which an ADAS can be used increasingly transform drivers into operators which compromises the ability of those 'operators' to intervene in control of the vehicle if the ADAS can no longer handle the situation. The opportunity to drive for a considerable time with an ADAS performing a large part of the driving task has the potential to lull drivers into a false sense of security. Thus ADAS producers should design their systems so as to promote mental engagement in the driving task, either through requiring the driver to remain physically coupled to the vehicle controls or through requiring sufficient attention to the driving situation.

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