SWOV
INSTITUTE FOR
ROAD SAFETY RESEARCH

Advising on human factors for field trials with (partially) self-driving vehicles

R-2015-15

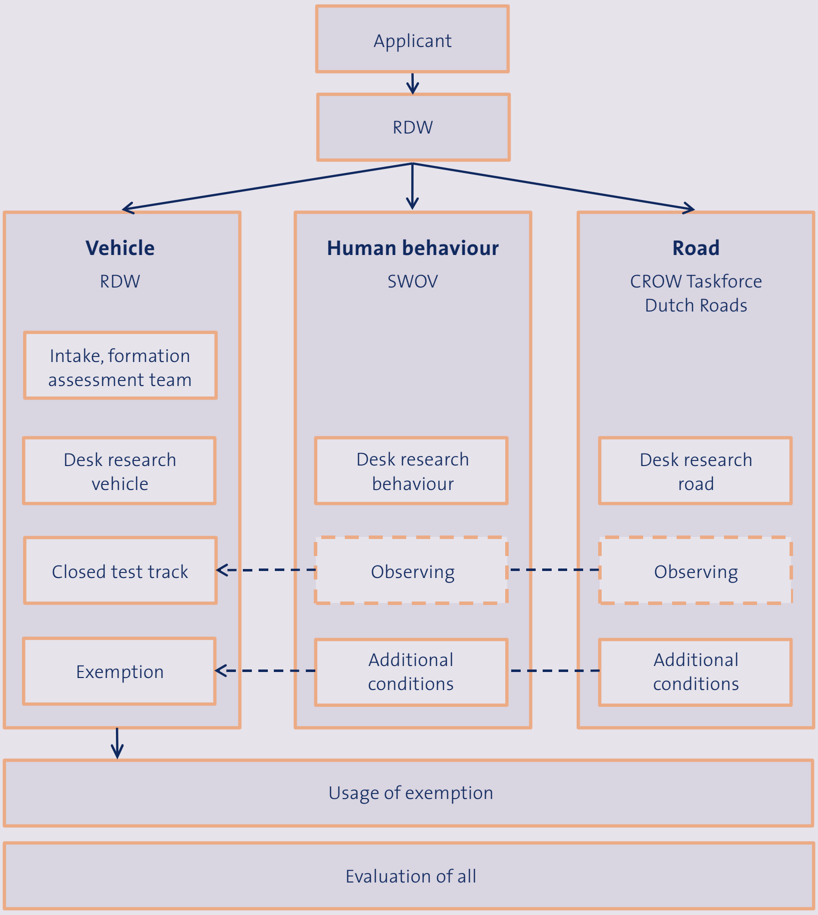

Figure 1: The exemption procedure (Ministry of Infrastructure and the Environment).

Introduction

Vehicles are increasingly equipped with systems that take over (elements of) the driving task. Eventually, this is expected to result in fully self-driving vehicles. The human role will shift from driver to supervisor, and ultimately to passenger. These systems are assumed to reduce the risk of human error and consequently to increase safety. At the same time, human factors will still influence the systems. After all, in the role of supervisor, human intervention is still necessary when the system requires it or in the case of system failure. Furthermore, it is still unclear how other road users will react to new systems.

To stimulate innovations concerning self-driving vehicles, the Netherlands facilitates the testing of self-driving vehicles on public roads. As road safety is the main prerequisite, the Ministry of Infrastructure and the Environment asked SWOV Institute for Road Safety Research for advice on how to carry out field trials with self-driving vehicles in the safest possible way.

The Ministry of Infrastructure and the Environment has drawn up the *Procedure for testing self-driving vehicles on public roads in the Netherlands*. This procedure is used as a guideline when filing a request for an exemption to allow field trials on public roads. The procedure (→*Figure 1*) consists of three closely interrelated components: vehicle, road and human (behaviour). RDW, the Dutch Vehicle Authority, coordinates the permission for a field trial. RDW is also responsible for the vehicle component. The road authorities or CROW Taskforce Dutch Roads are responsible for the road component, and SWOV is responsible for the (human) behaviour component. The test procedure has been designed in such a way that improvements can be made based on the experience gained in each trial. The test procedure is therefore continuously being developed.

To structure the safety advice on human behaviour, SWOV has developed a 'Risk matrix', describing potential risks of a field trial with (partially) self-driving vehicles. The Risk matrix is based on literature and expert knowledge.[1] It identifies potential risks involved in field trials and how they can be – or already have been – mitigated.

The Risk matrix is presented on the following pages. Its first dimension maps a number of risks in the following categories:

1. Risks due to the *interaction with the system/vehicle*;
2. Risks due to the *interaction with other road users*;
3. Risks due to the *location and moment* of the trial; the route and the place on the road are important considerations;
4. General risks due to project management.

The risks are (co-)determined by the level of automation of the system and the role (still) played by the driver. The second dimension of the matrix thus distinguishes three levels of automation:

a. *Partial automation – driver is active*
   At this level, the system temporarily takes over (elements of) the driving task – either steering or accelerating/braking. The driver performs all other dynamic driving tasks, such as monitoring the driving environment and the system. The driver functions as a fall back and needs to detect when action is necessary.
b. *Conditional automation – driver is important*
   The driving task is performed by the system. The driver performs the other dynamic driving tasks: monitoring the driving environment and acting as a fall back if this is indicated by the system. The driver now performs the role of supervisor.
c. *Full automation – driver is not important*
   The system takes over all driving tasks, monitors the driving environment as well as the system itself. The system detects if it is necessary to take action. The driver plays no active role in this vehicle and has now become a passenger. In some cases a remote operator will monitor the vehicle and the environment.

[1] SWOV used the FMEA method (as discussed in the ADVISORS project: ADVISORS (2003). *Advanced Driver Assistance and Vehicle Control System Implementations, Standardisation, Optimum Use of the Road Network and Safety: Final report*. Commission of the European Communities, Brussels.

The Risk matrix

	Partial automation	Conditional automation	Full automation
1. Risks due to interaction with the system/vehicle			
Training[2]	Have drivers been trained/informed on how to operate the system?		Has the operator been trained to take decisions?
New/different skills	Are drivers required to perform new or different tasks (e.g., overtaking with connected trucks, extreme long vehicles) and are drivers sufficiently equipped with the necessary competences?		Does the operator have enough information to make the right decision?
Mental workload[3]	Is driver's mental workload too high or too low?		
Situation awareness[4,5]	Does the driver stay 'in the loop' (aware of the traffic situation)? Will the driver be informed in time to be able to resume the driving task?		Will the operator (on the scene or from control room) be informed in time to be able to make correct decisions?
System failure[6]	Is a system failure communicated clearly?	Is a system failure communicated clearly and timely to take over control?	What happens when the vehicle stops unexpectedly (will this failure be communicated to the operator)?
Misuse of the system[7]	How will misuse of the system (e.g. switching on or off at the wrong time) be prevented?		
Unexpected events	Is there a protocol for unexpected events (e.g., animals/pedestrians crossing the street, objects or traffic jams on the road, flat tires)?		

[2] Larsson, A.F.L., et al. (2014). *Learning from experience: Familiarity with ACC and responding to a cut-in situation in automated driving.* In: Transportation Research Part F: Traffic Psychology and Behaviour, vol. 27, Part B, p. 229-237.

[3] Waard, D. de (1996). *The measurement of drivers' mental workload.* PhD Thesis University of Groningen, Groningen.

[4] Endsley, M.R. (1995). *Toward a theory of situation awareness in dynamic systems.* In: Human Factors, vol. 37, nr. 1, p. 32-64.

[5] Endsley, M.R. & Kaber, D.B. (1999). *Level of automation effects on performance, situation awareness and workload in a dynamic control task.* In: Ergonomics, vol. 42, nr. 3, p. 462-492.

[6] Strand, N., et al. (2014). *Semi-automated versus highly automated driving in critical situations caused by automation failures.* In: Transportation Research Part F: Traffic Psychology and Behaviour, vol. 27, Part B, p. 218-228.

[7] Marinik, A., et al. (2014). *Human factors evaluation of level 2 and level 3 automated driving concepts: Concepts of operation.* National Highway Traffic Safety Administration, Washington, D.C.

[8] Hoekstra, T. & Wegman, F. (2011). *Improving the effectiveness of road safety campaigns: Current and new practices.* In: IATSS Research, vol. 34, nr. 2, p. 80-86.

[9] Houtenbos, M. (2008). *Expecting the unexpected: a study of interactive driving behaviour at intersections.* PhD Thesis Delft University of Technology. SWOV Dissertation series. SWOV, Leidschendam.

[10] Sivak, M. & Schoettle, B. (2015). *Road safety with self-driving vehicles: general limitations and road sharing with conventional vehicles.* UMTRI-2015-2. University of Michigan Transportation Research Institute, Ann Arbor.

[11] Gouy, M., et al. (2014). *Driving next to automated vehicle platoons: How do short time headways influence non-platoon drivers' longitudinal control?* In: Transportation Research Part F: Traffic Psychology and Behaviour, vol. 27, Part B, p. 264-273.

[12] Skottke, E.M., et al. (2014). *Carryover effects of highly automated convoy driving on subsequent manual driving performance.* In: Human Factors, vol. 56, nr. 7, p. 1272-1283.

[13] Wegman, F. & Aarts, L. (2006). *Advancing Sustainable Safety; National Road Safety Outlook for 2005-2020.* SWOV, Leidschendam.

2. Risks due to interaction with other road users	Partial automation	Conditional automation	Full automation
Information[8]		Are other road users informed about the field trial?	
Predictability[9,10]		Is the vehicle response/behaviour in conformity with other road users' expectations?	
Traffic rules[9,10]		Does the vehicle follow the traffic rules?	
Misuse		Is there enough consideration for misuse of the system by other road users (e.g. other road users testing if the vehicle indeed stops automatically)?	
Copycat behaviour[11,12]	What is the chance of other road users copying behaviour of autonomous vehicles inappropriately (e.g. short headways (<5m) imitating platooning trucks)?		

3. Risks due to location and moment of the trial	Partial automation	Conditional automation	Full automation
Position on the road: mass, speed and size[13]	Is the proposed position on the road the safest one if the vehicle interacts with other road users?		
Route: speed and obstacle protection[13]	Is the speed of the vehicle appropriate for the circumstances (e.g. not too fast or too slow in the circumstances)? Are roadside objects and obstacles sufficiently shielded?		
External circumstances: weather and traffic	Are unfavourable weather conditions and heavy traffic taken into account?		

4. General risks	Partial automation	Conditional automation	Full automation
Project design and management	Is an incident response protocol available?		

SWOV procedure

Procedure for assessment of field trial

For each specific field trial, SWOV will put together an expert team.[14] In a brainstorm session, the risks that may play a role during the field trial will be determined. This will be done on the basis of the team's expertise, but if necessary an additional literature study and/or consultation of relevant national and international external experts will be carried out. The Risk matrix is used to ascertain that all potential risks are considered. However, potential risks are not limited to the risks earlier formulated in the Risk matrix. Any additional risks will be included in the Risk matrix and considered for future application.

Next, the experts individually evaluate in qualitative terms what the chances are that the risk will manifest itself as a critical situation and what the consequences are in terms of injury (* = small, ** = medium and *** = large). The modus (the most frequent occurrence) is determined for the final assessment of *risk and consequence*. Only potential risks evaluated with at least 2 x 2 asterisks are indicated as relevant risk and included in the final recommendations.

This risk/consequence assessment can not be quantified and it therefore does not evaluate the absolute risk or consequences in terms of injury. The assessment is only used as an indication of the risks that are viewed upon by the experts as most relevant.

Knowledge retention from the field trial

After the trial has been conducted, SWOV will evaluate it on the grounds of the available information. Questions arising may be: Have the risks identified occurred? Have certain risks been missed? Are lessons to be learned for comparable trials or for a wider out-roll in the future? This evaluation will finally be added to the advice and saved for future reference. Moreover, developments in academic literature and field experience abroad will be carefully monitored.

Background report

M.J. Boele, C.W.A.E. Duivenvoorden, A.T.G. Hoekstra & S. de Craen (2015). *Procedure en criteria voor de veiligheid van praktijkproeven op de openbare weg met (deels) zelfrijdende voertuigen; Achtergrond en aanpak van het SWOV-veiligheidsadvies*. R-2015-15A. SWOV, The Hague. [In Dutch]

[14] At SWOV, knowledge on human behaviour in traffic and road safety is embedded in two departments (Human Factors and Road Safety Assessment) with over 30 specialists from different scientific backgrounds working interdisciplinary to improve road safety. From these specialists, a team with the relevant expertise is selected, if necessary complemented with expertise from outside SWOV.

Prevent crashes

Reduce injuries

Save lives

Colophon

Authors

Dr Saskia de Craen

Marjolein Boele, MSc

Kirsten Duivenvoorden, MSc

Tamara Hoekstra, MSc

Photography

Paul Voorham, Voorburg
Peter de Graaff, Katwijk

© 2015

SWOV Institute for Road Safety Research
PO Box 93113, 2509 AC The Hague, The Netherlands
Bezuidenhoutseweg 62, 2594 AW The Hague
T +31 70 3173 333
E info@swov.nl
I www.swov.nl

@swov_nl / @swov
linkedin.com/company/swov

This study has been financed by the
Ministry of Infrastructure and the Environment.

This publication contains public information.
Reproduction is permitted with due acknowledgement.