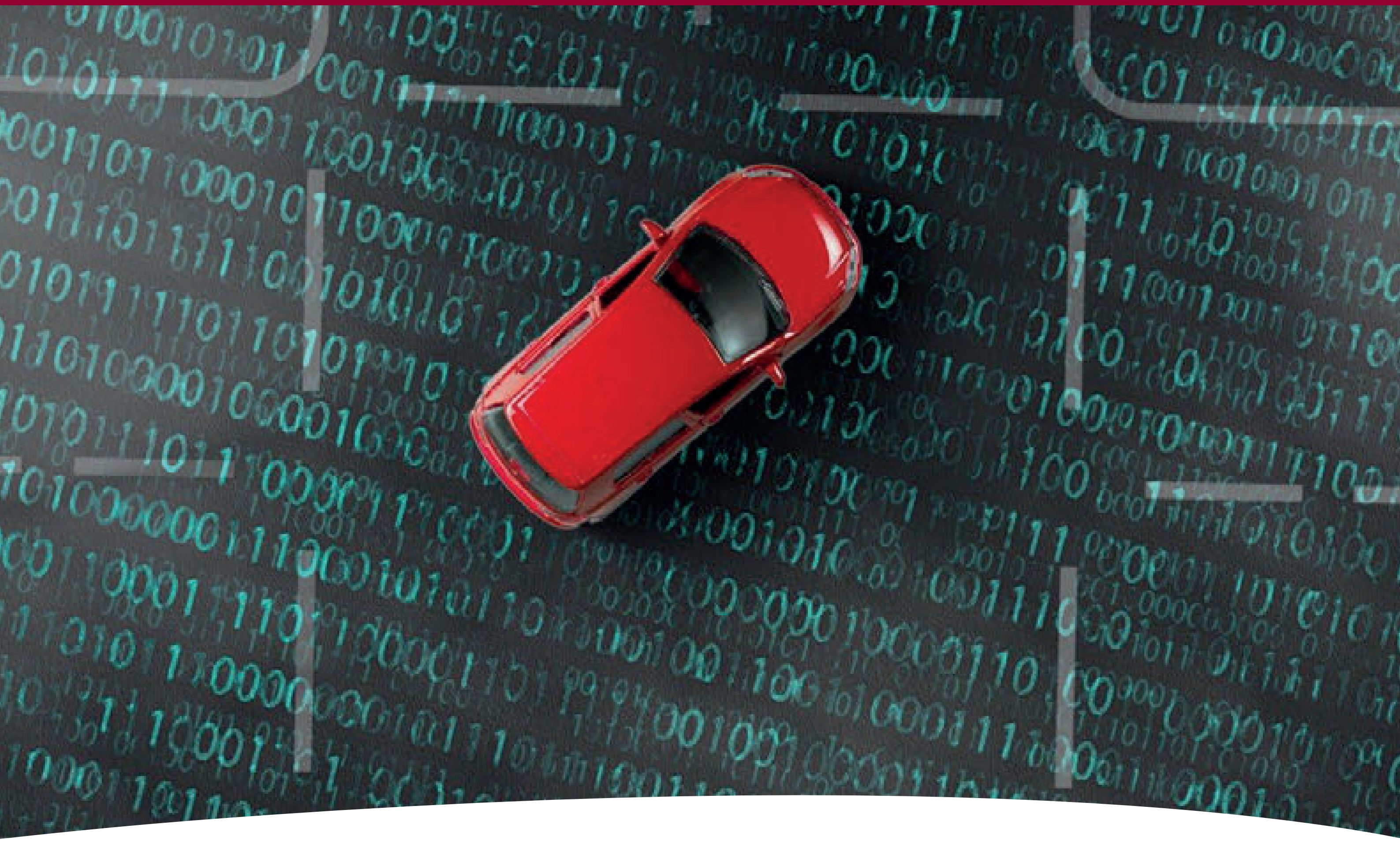
GDV | The German Insurers No. 78



Does automated driving improve safety?

Compact accident research

Unfallforschung der Versicherer
GDV

Content

Introduction

Automated driving is regarded as the future of mobility. It is expected to make traffic flow more efficiently and reduce the number of road accident victims as well as emissions and traffic jams. This will be more of a multi-dimensional, gradual transition than a rapid change.

The new technology will be available in both cars and commercial vehicles. Currently, these vehicles offer either Level 2 (partial) or Level 3 (conditional) driving automation, which is typically active only on motorways [1]. As the development of the technology continues, vehicles with higher levels of automation that are also suitable for use in other situations, not just on motorways, will gradually become available. The situation is somewhat different with parking functions. Here, development may proceed more quickly toward highly automated functions.

What we can say today is that vehicles with different levels of automation will be sharing the roads with manually driven vehicles in the foreseeable future. This development will affect both cars and commercial vehicles.

Categorizing and distinguishing between modern assistance and automation functions

The discussion around automated driving requires a clear understanding of the attributes and capabilities of the functions involved.

Driving can be subdivided into navigation, vehicle control and stabilization tasks [2]. According to this model, the navigation level is about route planning, the vehicle control level involves the driver comparing the goal with the current situation (i.e. dynamic driving), and the stabilization level is about controlling deviations in a closed loop system.

Assistance and automation functions operate on the vehicle control level. There are three different modes of action here [3]: informative and warning functions, continuously automating functions and temporarily intervening systems (see table 1).

This approach has the advantage that a distinction can be drawn between advanced driver assistance systems and automated driving functions. Even among advanced driver assistance systems, there are differences that are clearly based on their mode of action. Mode of action B describes the levels of automation under discussion (see table 2). Level 1 covers only advanced driver assistance systems that handle longitudinal and lateral control. These are the proximity control system and the lane-keeping assist system. The lane-departure warning system, on the other hand, comes under mode of action A/2.

Table 1: Assistance and automation functions on the vehicle control level [3]

Mode of action A **Informative and warning functions**	**Mode of action B** **Functions offering continuous automation**	**Mode of action C** **Systems that intervene temporarily in accident-prone situations**
Take effect exclusively and "indirectly" through the driver: 1. Status information, e.g. traffic-sign recognition 2. Abstract warning, e.g. lane-departure warning system 3. Concrete warning, e.g. • Blind-spot detection system or • Collision warning system	Have a direct effect on vehicle control, can always be overriden. Definition according to SAE J3016 [1] or VDA/BASt [4]	Preventive machine intervention with a negative situation forecast, e.g. • Emergency brake assist system • Emergency steering assist system

Table 2: Levels of automation in accordance with SAE J3016 and VDA/BASt [1] [4]

Nomenclature	Driving tasks of the driver by level of automation
Full automation Level 5	The system takes full control of driving on all road types and in all speed ranges and environmental conditions
High automation Level 4	The system takes over full lateral and longitudinal control in a defined application
Conditional automation Level 3	The system takes over lateral and longitudinal control for a certain period in specific situations
Partial automation Level 2	The system takes over lateral and longitudinal control (for a certain period and/or in specific situations)
Driver assistance Level 1	The driver has constant lateral or longitudinal control. The other driving task is handled by the system within certain limits (e.g. adaptive cruise control (ACC) system, lane-keeping assist system).
No automation Level 0	The driver drives constantly (for the whole journey) with both longitudinal control (acceleration and breaking) and lateral control (steering).

Effect on road safety

3,177 people died on German roads in 2017, and 388,200 were injured [5]. Figure 1 below shows the fatalities by type of road use in 2016.

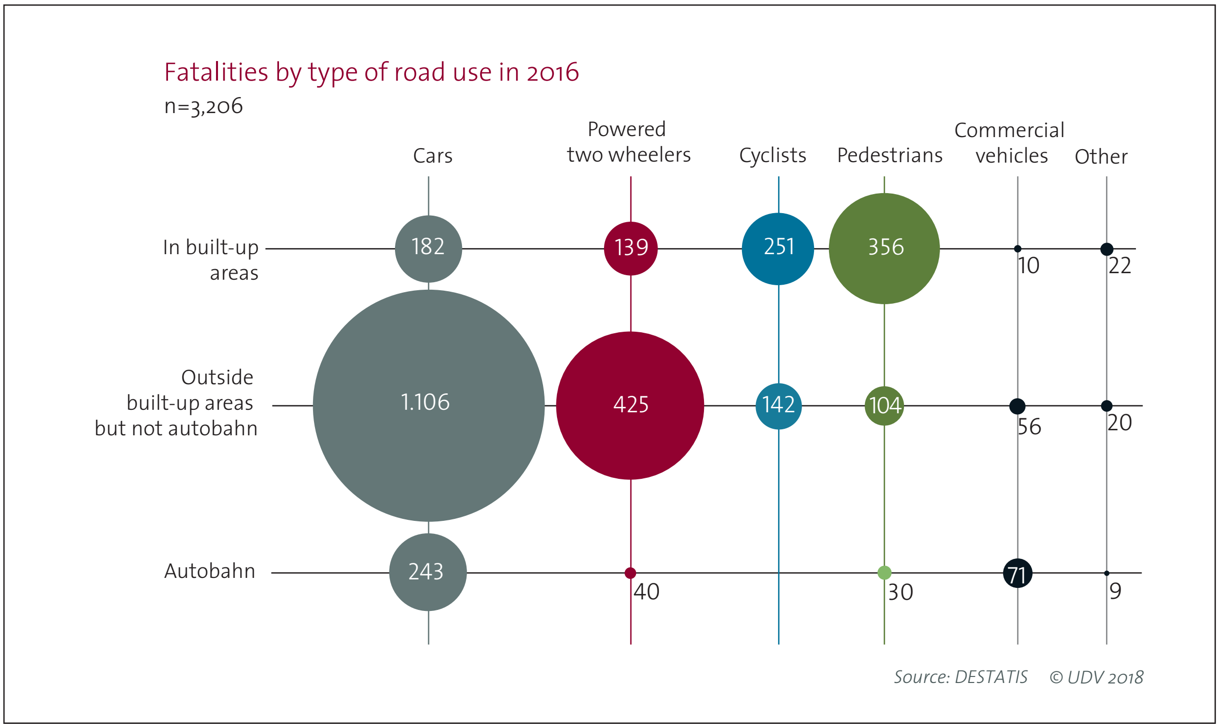


Figure 1: Fatalities by type of road use in Germany in 2016 [6]

It becomes clear that most fatal accidents involving cars take place outside built-up areas. Accidents caused by leaving the roadway and colliding with trees are a key factor. Accidents involving two-wheel motor vehicles outside built-up areas – motorcycles, in particular – come second in the accident statistics. The third problem group consists of unprotected road users in accidents in built-up areas. These are primarily pedestrians and cyclists who are killed in collisions with cars.

Effect on road safety

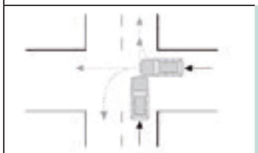
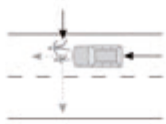
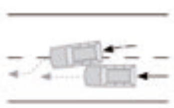
Advanced driver assistance systems

The aim of new technologies should be to address the most common, most serious types of accidents and have a positive impact on them. The calculations in table 3 indicate this. Emergency brake assist systems are very important for car accidents. They address common accident scenarios such as accidents in longitudinal traffic (22 percent) and also have some impact on accidents at intersections and junctions. Almost 20 percent of all car accidents would be avoidable with an emergency brake assist system that could detect double-track vehicles in front, whether moving or stationary.

If the emergency brake assist system could also detect pedestrians, it would be able to prevent 24.5 percent of all car accidents. The consumer protection organization Euro NCAP has included these systems in its new car assessment program since 2016 [8]. A regulation requiring all cars to be equipped with these valuable safety systems is planned and should be implemented by some time in the middle of the next decade [9].

There is a need for action, above all, at intersections and junctions, where the largest number of car accidents (around a third of the total) occur. From 2020, a system that addresses accidents where vehicles cross each other will be included in Euro NCAP [8]. By then, at the latest, these sys-

Table 3: Accident scenarios and safety potential of advanced driver assistance systems for cars [7]

Car accident scenarios		Advanced driver assistance systems	Safety potential*
	34.5%	Junction assistance system	
	22.2%	Emergency brake assist system	SP=19.6%
	15.5%	Oncoming-traffic assistance system. lane-keeping assist system	
	12.1%	Emergency brake assist system with pedestrian detection	SP=24.5%
	6.9%	Lane-keeping assist system. blind-spot warning system	SP=6.1%
	6.3%		

* in relation to all car accidents in the insurers' accident database (UDB)

tems will be increasingly coming onto the market in Europe and having a positive impact on the accident statistics.

Automation functions

On the basis of the insurer's accident database (UDB), initial deductions with corresponding assumptions lead to the road safety potential of a generic conditional automated driving function (CADF) for cars and trucks shown in figure 2 [8]. The simplified assumption in this approach is that an automated driving function is distinguished, above all, by the addition of the safety potential of the emergency brake assist system, the lane-keeping assist system and the blind-spot warning system. Not yet taken into account in this are conceivable and, in a transitional phase of mixed traffic consisting of automated and conventional vehicles, probable negative effects of the automated driving function in the accident statistics, because they are not yet quantifiable.

It is becoming clear that an automated driving function for cars on motorways would be of only minor benefit in terms of road safety (4.5 percent of all car accidents). By contrast, the function would deliver clear added value for trucks on these roads. There could be a positive impact on 14.5 percent of all accidents involving trucks. On the other hand, an automated driving function for cars could have a positive impact on around 33 percent of accidents in built-up areas, above all, and thus improve road safety. However, the demands on the technology are clearly higher than those on motorways due to the complexity of the traffic situations in built-up areas. Consequently, initial applications in cars in the near future will address driving on motorways.

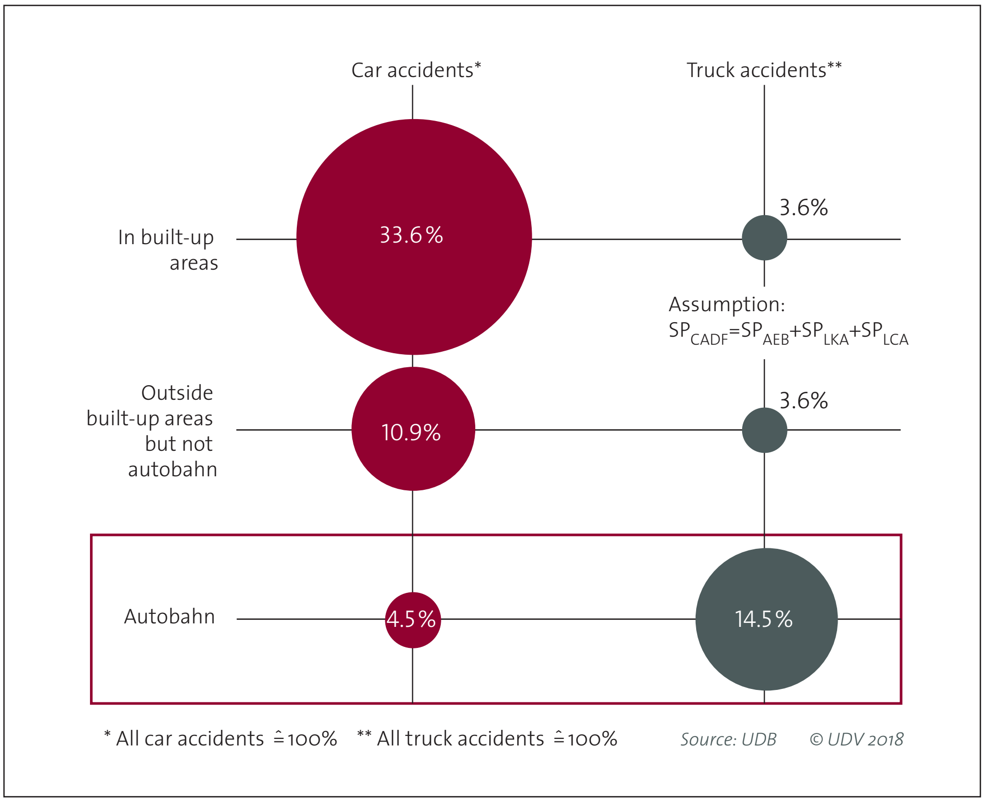


Figure 2: Impact of the conditional automated driving function on the accident statistics in Germany [10]

Effect on road safety

A GDV study analyzed the damage costs incurred by insurers up to 2035 [11]. It is clear from this that it will not be possible to prevent many forms of damage regulated by the insurers by means of advanced driver assistance systems and automated driving functions (figure 3). These include theft, flying stones, hail or damage caused by martens. The new technology will also lead to increased repair costs, since it involves additional sensor systems in the vehicle. When it comes to the dissemination of the technology in the vehicle fleet, one fundamental point applies both to advanced driver assistance systems and automated driving functions. These new systems will initially only be offered in selected new vehicles in the upper segments of the market. It also has to be taken into account that the average age of vehicles in Germany is constantly increasing. All of this means that the systems will not be integrated in virtually all vehicles until long after their market launch, and their positive impact on road safety may thus be significantly delayed. For this reason, too, the study comes to the conclusion that, even if advanced driver assistance systems and automated driving functions spread quickly, the damages paid by insurers for car insurance by 2035 will be reduced by only around 15 percent. Drivers cause an accident involving injury only once every three million kilometers on average [12]. The key criterion to be met is that the automated systems under discussion must reach at least the level of safety as the systems controlled by drivers today. It should be possible to demonstrate their safety clearly by means of a transparent process, and this process may also involve numerical methods.

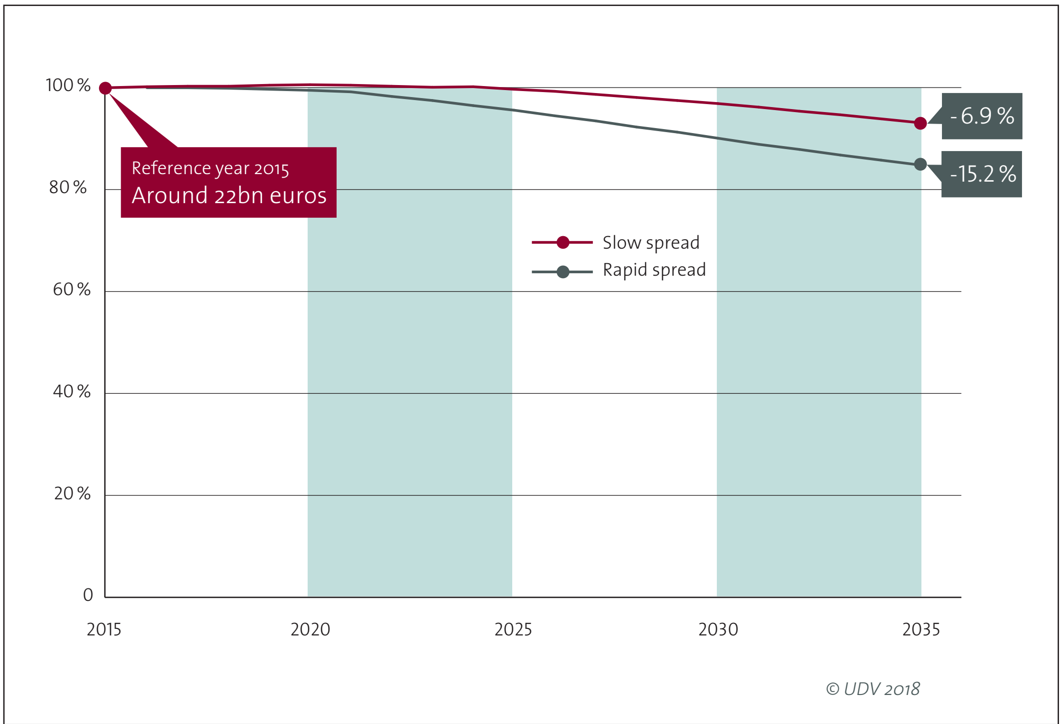


Figure 3: Trend in claims expenditure of vehicle insurance 2015-2035 [11]

Road safety must benefit from this technological development, but a long-term strategy is required. One reason for this is that applications such as traffic jam pilots and autobahn or freeway pilots will be available initially only on motorways. In addition, it will take a long time for these technologies to achieve significant market penetration in vehicles.

Limits of the technology: human drivers still central

If we look at the near future, we can say that partial and conditional automated driving will still require drivers to be in control of the situation and intervene whenever there are problems. It should be possible for drivers to exercise this control, although there is at least a risk that they will not know the limits of the system's functionality and that these limits will differ from one vehicle to another. Drivers will have to clearly understand what their vehicles are capable of doing and where their responsibility lies.

It is unlikely that the transport infrastructure will be adapted in the short term in order to make the roads more suitable for driverless vehicles. Instead, the capabilities of these vehicles will have to improve greatly if they are to be able to drive autonomously on all kinds of roads. However, researchers and developers also expect cities to have automation zones in future, in which vehicles will be monitored, and goods and people will be transported autonomously and cooperatively [13].

The first vehicles that can be driven with partial automation are now available. The driver must remain attentive while the automated functionality is activated and monitor the system constantly. Many years of research in different disciplines has shown that humans are unable to perform this kind of monitoring task flawlessly. This could result in new kinds of accidents involving these vehicles. The situation is complicated by the fact that modern vehicles will offer different driving functions with different levels of automation. These include functions that also have very different applications: For example, vehicles will provide conditional or highly automated parking functions and, at the same time, partially automated driving functions on motorways. Less clear and thus potentially more problematic for drivers are functions in the same field of application. A vehicle that is capable of Level 4 automated driving on motorways in ideal conditions may only offer partially automated longitudinal and lateral control if conditions worsen. It is critical in this case for drivers to understand both the limits of the system's capabilities and their own responsibilities. Ideally, transitions between assisted and automated driving functions should be implemented by means of a clear human-machine interface in the vehicle. One good option could be to use the steering wheel as a new visual interface for automated driving functions. When the vehicle takes over responsibility, the steering wheel clearly changes color. In the case of assisted driving functions in which the driver has the responsibility, the steering wheel does not offer any information – just like in today's cars.

In the coming years, systems will become available that will be able to drive autonomously for certain periods of time but will only be able to handle selected situations. This is referred to as conditional automation. The driver no longer has to monitor the vehicle continuously but does have to take control on request when the system limits are reached.

The fundamental problem described here in connection with constant monitoring coupled with intervention in the event of critical situations is based on a human characteristic investigated by psychologists over 100 years ago [14]. The resulting Yerkes-Dodson law describes the general relationship between a person's ability to perform well and their state of physiological and mental arousal. When a person has a low level of arousal, their performance remains at a minimum level. As the person becomes more aroused, their performance increases up to a maximum level. If arousal increases beyond that, performance starts to drop again until it reaches a similar minimum level to the level at low arousal (figure 4). Put simply, this means that people perform demanding tasks best with a moderate level of arousal. Driving a car is such a task. Monotonous tasks, like driving down a perfectly straight road with no traffic, can result in a low level of performance or failure. Monitoring a Level 2 autobahn or freeway pilot is one such task. Equally, if a driver is overtaxed, the result will be poor performance and

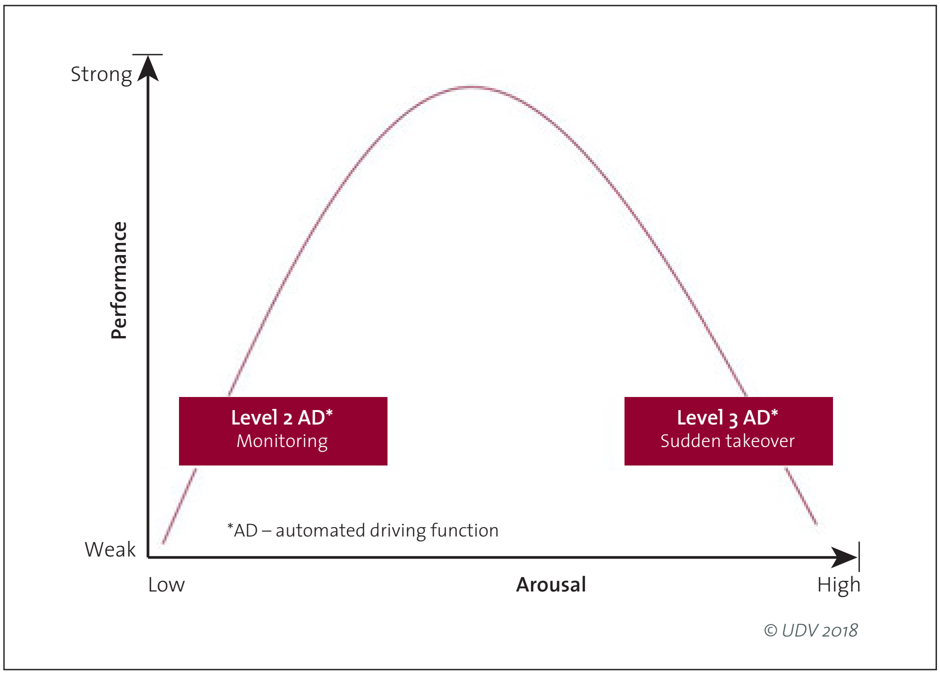


Figure 4: Simplified representation of the Yerkes-Dodson law in connection with automated driving [14]

even failure. Suddenly being requested to take over control from a Level 3 autobahn or freeway pilot would be an example of this.

According to the current status of the discussions around a UNECE regulation to put in place a technical standard for systems offering partial automation, drivers may will be given only four seconds to safely take over control of the vehicle. However, the latest results of research carried out by the Technische Universität Braunschweig (TU Braunschweig) indicate that a well-rested driver engaged in an engrossing secondary task needs around eight seconds to take control even after a short spell of control by a conditional automation system, and around 14 seconds to get full control over the situation [15]. The times for a tired driver are similar even without a secondary task. In addition, another TU Braunschweig study shows that drivers get tired significantly more quickly when their vehicle is in conditional automation mode, and that an automated drive (Level 2 and 3 systems) lasting longer than 15 minutes is therefore inadvisable if the driver is required to take over control at short notice [16].

Table 4: Key characteristics of assisted and automated driving functions [17]

	Manual/assisted	Automated
(1) Naming	The name or description of the system must be unequivocal and clearly describe the system's functionality. It must not in any way imply that the function is automated.	The name or description of the system must be unequivocal, clearly describe the system's functionality and include the term "automated".
(2) Law abiding	How the vehicle behaves must comply with the traffic laws and the highway code.	During operation the system must comply with local traffic laws, including adhering to the speed limit and maintaining a safe distance from the vehicle in front. How the vehicle behaves must comply with the traffic laws and the highway code.
(3) Location specific		The operation of each function must be geo-fenced in order to ensure that it remains within its intended scope and makes the driver aware of where it is available and where it is not.
(4) Clear handover	The status of the driving function, manual or assisted, must be clear and unequivocal, and it must be clear when control is transferred. The system must continuously monitor operation to ensure that the driver is doing what is required.	The handover of control to the driver and back to the system must follow a process in which the system indicates its availability, and the driver must confirm he or she has taken over and vice versa. This requires the system to be able to "see" far enough in advance in order to maintain safe operation if the handover of control from the system to the driver fails.
(5) Safe driving	The driver must be made aware clearly and explicitly of his or her responsibility to drive safely and deal with foreseeable traffic situations within the system's intended scope that the system cannot handle safely.	When the system is in automation mode, the vehicle must be capable of handling all situations that occur and can realistically be expected within its intended scope.
(6a) Avoidance of improper use	The vehicle must recognize it if the driver is using the system incorrectly and take action to prevent this. If warnings are ignored, this should result in the system being deactivated. Continual improper use must result in the system being switched off until the vehicle is next started.	The vehicle must recognize it if the driver is using the system incorrectly and take action to prevent this.

▶

Limits of the technology: human drivers still central

	Manual/assisted	Automated
(6b) **Unexpected handover**		If the automated vehicle detects a situation that was not foreseeable at the beginning of the automated drive (e.g. bad weather), and this leads to handover of control to the driver earlier than planned, the driver must be notified in an appropriate way.
(7) **Safe stop**		If the driver does not respond to a request to take over control, the vehicle has to execute a safe stopping maneuver and head for a safe location that falls within its intended scope and is appropriate for the traffic conditions.
(8) **Emergency intervention**		If the vehicle detects a sudden unforeseen dangerous situation, the system must execute a risk-minimizing maneuver to mitigate or avoid a collision.
(9) **Back-up systems**		In the event of a fault, the system must have enough redundancy in place to either be able to continue in automation mode or execute a planned handover of control to the driver. Each fault must be indicated to the driver and, if appropriate, the use of the system must be prevented or restricted until the fault is corrected. The system must be capable of self-diagnosis and detecting faults. It must also be self-calibrating.
(10) **Accident data**		Data that enables accidents to be explained must be recorded in case of a collision and be made available equitably to manufacturers and third parties who are authorized to see it. As a result, questions regarding the status of the automated system, the extent of what the driver did and liability can be quickly and independently evaluated.

Technical requirements to be met by automation functions

Based on a clear understanding of the possibilities and limits of automation functions, it is useful to describe the requirements to be met by concrete road safety-related aspects of these systems (table 4). Clear communication of how the functions work and what they are capable of prevents the driver from becoming confused.

As already mentioned, vehicles with automation functions will also be involved in traffic accidents. It is of key importance to be able to identify vehicles with these automated driving functions and give authorized third parties standardized access to data to allow them to investigate with as much precision as possible how an accident happened and who or what was responsible. From a road safety point of view, the data should contain at least:

- A GPS event: location and time of the event
- The automation status – on or off
- The automation mode – parking or driving
- The automation transition: timestamp
- A recording of the driver's intervention: steering, braking, accelerating, indicating
- The time since the driver's previous intervention
- Whether the driver's seat was occupied and the driver's status
- Whether the driver's seat belt was fastened

Only then will it be possible in future to enable traffic accident researchers to ascertain the causes of accidents involving vehicles with automated driving functions and draw the right conclusions so that the systems can be further developed.

Conclusion

Highly automated and autonomous vehicles could bring great benefits in terms of road safety if they functioned flawlessly under all conditions within their intended scope. Until such time as these systems come onto the market, drivers of manually controlled vehicles should benefit in terms of road safety from continual improvements in assistance systems. In this transitional phase, automated functions will nevertheless be offered that require the support of the driver. If these are not to represent a threat to road safety, they should have the key characteristics presented here. As a general principle, vehicles with automated driving functions should only be used on public roads provided they are not less safe than corresponding vehicles equipped with advanced driver assistance systems.

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Notes

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