



# Assisted Driving Functions (L2) on rural roads

Suitability, development of representative test scenarios and evaluation of driving behaviour



**Gesamtverband der Deutschen Versicherungswirtschaft e. V.**  
**(GDV – German Insurance Association)**

Unfallforschung der Versicherer (UDV – German Insurers  
Accident Research)

Wilhelmstraße 43 / 43 G, 10117 Berlin

Postfach 08 02 64, 10002 Berlin

Tel. 030 2020–5821, Fax 030 2020–6633

[www.udv.de](http://www.udv.de), [www.gdv.de](http://www.gdv.de), [unfallforschung@gdv.de](mailto:unfallforschung@gdv.de)

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**Editorial work**

Dr. Matthias Kühn, Jenö Bende (UDV)

Hatun Atasayar, Maria Scheibmayr

(Kuratorium für Verkehrssicherheit, KFV)

Markus Deublein, Jasmin Zimmermann

(Beratungsstelle für Unfallverhütung, bfu)

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# 1. Introduction

This accident research summary is based on the findings of UDV research report no. 100: “Assisted driving functions on rural roads – suitability and development of representative test scenarios and evaluation of driving behavior.”

Since the year 2000, it has been the goal of the European Commission to halve the number of road traffic fatalities every ten years. By 2050, there should no longer be any road traffic fatalities (Vision Zero). While this goal still appeared to be achievable in the early 2000s, the positive trend has since flattened out, in particular during the years from 2015 to 2020 [1]. Researchers suspect that the effect of passive safety, which has improved greatly since the change of millennium, is increasingly being balanced out by accidents due to higher levels of driver distraction [2,3].

Reducing the extent to which drivers are involved in the driving task (due to the increased support provided by L2 driving function in accordance with UNECE R79 risks further exacerbating this problem. This is because it brings with it the danger that drivers progressively become less involved in the driving task (reduced driver engagement), while nevertheless having to intervene immediately in safety-critical situations when the technology reaches its limits. The technology used in today’s L2 driving functions [4] is the result of integrating various advanced driver assistance systems (ADAS, e.g. adaptive cruise control, lane departure warning and emergency braking assistant). Although L2 driving functions such as these support drivers in the longitudinal and lateral control of the vehicle, they nevertheless require them to keep their hands on the steering wheel at all times and continuously monitor the system functions. The driver must intervene in good time if the system malfunctions or reaches its limits. To intervene quickly and safely, it is necessary to be sufficiently aware of the current situation, meaning that the driver must remain actively involved in the driving task.

Although L2 driving functions were developed for use on motorways and similar roads, there are no legal restrictions limiting their area of use: In principle, they can therefore also be used on rural roads. However, due to the many infrastructural challenges they pose, rural roads place special demands on these technologies. The (safe) use of L2 driving functions on rural roads therefore raises the fundamental question of whether or not L2 driving functions are suitable for use on rural roads.

In compliance with the requirements of the General Safety Regulation (EU) 2019/2144 [5], certain ADAS features for improving road traffic safety have had to be fitted in new vehicles since 2022, and in all newly registered vehicles since 2024. This should also contribute to the market acceptance of L2 driving functions, which were primarily developed to improve the driving experience. In the near future, new technical regulations for further developed systems will take effect

(UNECE R171 (DCAS)) and these will go beyond the L2 driving functions approved under UNECE R79 that are currently available on the market. The consumer testing organisation Euro NCAP is currently evaluating L2 driving functions on the basis of a protocol that rates not only the technical requirements but also, for example, the way the driver is involved in the driving task [6].

While assisted driving using L2 driving functions has a positive impact on safety (e.g. better/more constant distance control, lane-keeping), it also brings with it many new challenges that might impair traffic safety (see Section Fehler! Verweisquelle konnte nicht gefunden werden.). These problems were set out as far back as 2019 in a joint position paper issued by the three research institutes – the Kuratorium für Verkehrssicherheit (KFV), the Beratungsstelle für Unfallverhütung (bfu) and the Unfallforschung der Versicherer (UDV) [7]. In it, they express the view that people should either always drive themselves supported by state-of-the-art driver assistance systems or should be driven by an autonomous driving function. All developments between these two positions conceal risks for traffic safety that must be prevented by means of technical measures. Analyses conducted by the UDV have already shown that advanced driver assistance systems are the most beneficial for traffic safety [8].

That is why the consortium requested proposals for a research project intended to examine the performance and safety of current L2 driving functions on rural roads as well as their impact on driver engagement.

The research project had two main objectives:

1. To examine the performance and safety of modern L2 driving functions on rural roads
2. To examine the impact of L2 driving functions on driver engagement

To do this as effectively as possible, the functionality of the L2 driving functions was first tested in real traffic and then under controlled test conditions at the test site. Three critical test scenarios that are representative of rural roads were developed to test the functionality.

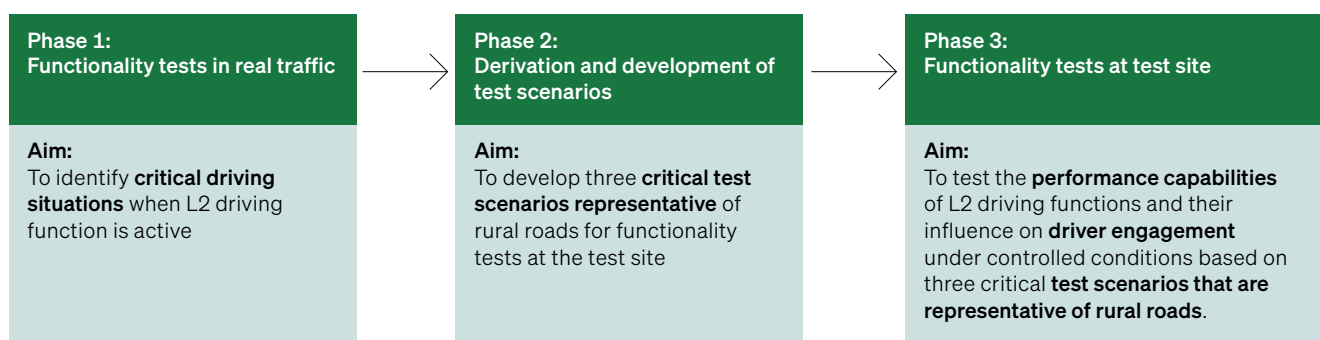
## 2. Methodology

The research project was structured into three phases. During the first project phase, the functionality of the systems was tested in real road traffic in order to assess the performance capabilities of L2 driving functions on rural roads. The main aim was to identify critical driving situations.

Based on the results from phase 1, the second phase consisted in developing three safety-critical test scenarios that were representative of rural roads. In the third phase, these scenarios were used to examine the performance capabilities of L2 driving functions and their influence on driver engagement under controlled conditions on the test track (see Figure 1).

### The project was carried out in three phases, from the identification of critical driving situations to the development of test scenarios

Figure 1 · The three phases of the research project



### 2.1. Functionality tests in real traffic

#### Choice of the test route

The test route passed through Austria, Germany and Switzerland in order to take account of national differences in topography, lane markings and road signs and make it possible to obtain informative results valid for all three countries. The various route sections consisted primarily of rural roads on which it was possible to activate the L2 driving functions and use these for extended periods.

First of all, geoinformation systems (GIS) were used to identify potential itineraries. Because the functionality of the automated lateral control and steering assistance systems depends to a very large extent on the lane markings, the route sections were then subdivided into five categories based on the quality of the lane markings (see Table 1) and the suitability of the routes for L2 driving functions was assessed.

## Only sections with fully marked lanes were deemed suitable

**Table 1** · Categorisation of the route sections

Category	Explanation	Assessment
1	Carriageways with complete marking (border line on right, directions of travel separated by central line on left)	Highly suitable
2	Carriageways with only border lines on right and left (no central line)	Suitable with limitations
3	Carriageways with central line but no border line	Suitable with limitations
4	Unmarked carriageways	Unsuitable
5	Unmade, unmarked carriageways	Unsuitable

Category 1 was identified as highly suitable for the use of L2 driving functions because it permits the reliable activation of these functions. In categories 2 and 3, the functionality of the lateral control systems is sometimes restricted because it is difficult for the camera-based sensor system to identify the centre of the carriageway. In the case of categories 4 and 5, it was not considered possible to activate the L2 driving functions.

Overall, 66.7 % of the total distance of 231.9 km consisted of rural roads (open road), 14.4 % was accounted for by motorways and 18.8 % by roads in built-up areas. 58 km (25 %) of the overall route passed through Switzerland, 130 km (56 %) through Germany and 44 km (19 %) through Austria. 60.1 % of the chosen route (see figure 2) had sections of category 1 with a speed limit of over 60 km/h. Consequently, more than half of the test route was fully compatible with the purpose of the study.

## The chosen route passed through Austria, Germany and Switzerland

**Figure 2** · Chosen test route - Circuit around Lake Constance



## Test Vehicles

To make sure that it would be possible to compare the results, the vehicles chosen to test the system functionality in real traffic were all equipped with L2 driving functions, including the sub-functions listed in Table 2. They also covered various vehicle segments (volume models, premium segment, technological innovations) and possessed an up-to-date Euro NCAP rating, including the Euro NCAP Assisted Driving grading (if present).

L2 driving functions take over the longitudinal and lateral control of the vehicle in a given operational design domain (ODD), while the driver continues to have to monitor the traffic situation. L2 driving functions consist of a combination of individual systems introduced and further developed over time. They have primarily been developed for use on roads with infrastructures that comply with regulations (e.g. road signs, carriageway markings), in particular such as those found on motorways.

### Modern driver assistance systems were included in the range of functions of the test vehicles

**Table 2** · Choice of function scope for the test vehicles (minimum requirements); highlighted in bold: L2 function scope

Longitudinal control	Lateral
Intelligent ACC	Emergency Lane Keeping Support (ELKS)
Adaptation to speed limit	Lane Centering Assist (LC)
Curve Speed Assist (CSA)	Lane Change Assist (LCA)
Roundabout assistant	
Autonomous Emergency Braking (AEB)	

One premium segment vehicle, one compact model and one midrange car were chosen:

- Vehicle A (premium segment)
- Vehicle B (compact class)
- Vehicle C (midrange)

All the test vehicles had electric drives.

### Identification of critical driving situations

Critical driving situations (referred to as “trigger events” below) were mostly identified orally by the drivers, who said the word “trigger” aloud during the journey if one or more of the following occurred:

- 1. Need to intervene:** The test driver had to intervene actively in the driving activity by braking, steering or correcting the system.
- 2. System failure:** The system did not function correctly and transferred control of the vehicle to the driver.
- 3. Unusual situations:** These comprised situations in which the driver would have acted differently if the L2 driving functions had not been active

## Rating of the criticality of trigger events by the driver

The drivers gave an oral subjective rating of the criticality of each situation on an 11-point scale by answering a question (“How critical was the situation?”). Answers from 0 to 3 were considered to reflect an “uncritical situation”, 4 to 6 a “moderately critical situation”, and 7 to 10 a “critical situation”.

Criteria making it possible to describe the event were also recorded for each trigger event (e.g. weather). An overview of the criteria can be found in Appendix A of the full research report no. 100 of the UDV.

The subjective rating of the criticality of the various situations is part of the method for the “Evaluation of Man-Machine-Interactions during partially-automated driving” [9].

## 2.2. Development of the test scenarios

The aim was to develop three safety-critical, concrete, realistic scenarios representative of rural roads that could be used during the functionality tests at the test site in order to compare the different levels of driver engagement. The procedure was based on the scenario-oriented approach adopted by Menzel et al. [10], which provides a methodological framework for the systematic testing and validation of automated driving functions.

The approach involves defining and running test scenarios that simulate real traffic situations and are organised into different levels of detail. It comprises three main stages:

1. **Definition of functional scenarios:** First of all, functional scenarios are identified and defined. These describe a driving situation or driving task in general terms at a high level of abstraction.
2. **Derivation of logical scenarios:** Logical scenarios are derived from the functional scenarios. These contain concrete parameters such as vehicle speed or bend radii and therefore describe testable situations.
3. **Transposition into concrete scenarios:** Finally, the logical scenarios are transposed into concrete scenarios. In these, all the parameters are adapted to the specific test environment and test setup and are precisely defined.

### 2.3. Functionality tests at the test site

#### Test site

The functionality tests were conducted at the DSD test site in Hofkirchen, Austria, (see Figure 3). The test site is certified for Euro NCAP tests of active safety and therefore meets the necessary standards in terms of carriageway properties.

#### Test track certified according to Euro NCAP specifications

**Figure 3** - Section of the test track with the employed carriageway markings (source: DSD)



#### Evaluation of the Man-Machine Interaction

The aim of the method referred to as “Evaluation of Man-Machine Interaction during partially-automated driving” [9], also known as the handling rating, is to evaluate the efficiency and safety of MMI on the basis of specific test criteria. The criteria evaluate the quality of the driver’s operating behaviour during system activation, the quality of vehicle control in the test situation (in particular the reaction to system behaviour when unexpected “trigger events” arise) and the quality of monitoring (i.e. compliance with the hands-on-wheel request). The method provides useful information for drawing conclusions about driver engagement, primarily on the basis of an analysis of monitoring and vehicle control because these aspects reflect the driver’s active engagement and attention in the driving situation.

The handling rating comprises two parts:

1. Rating of the test subject’s behaviour by two trained observers during activation of the systems and navigation of the scenarios.
2. Questionnaire-based rating of the navigated scenario and the trigger event by the test subject themselves immediately after the functionality test at the test site.

## 3. Results

The following sections describe the main results of the functionality tests in real traffic and the test drives on the test site.

### 3.1. Functionality tests in real traffic

In Phase 1 of the project, the system functionality was tested in real traffic. The tests were performed under real conditions on the public highway.

The results showed that it was possible to activate L2 driving functions on all the tested route sections on which adequate carriageway markings were present. On average, a trigger event requiring driver intervention occurred every five minutes (total of 262 events, including 139 on the rural road, over an evaluated test time of approximately 24 hours).

Trigger events primarily occurred due to inadequate lateral control and speed selection errors, with driver engagement playing a vital role in these situations. The following were observed particularly frequently:

- **Shortcomings in lateral control:** The vehicles tended to leave the carriageway or to enter the area reserved for oncoming traffic both in bends and on straight sections. Lane-keeping problems of this sort occurred when the Lane Centering Assist function shut down in a bend (sometimes without informing the driver of this), but also when the road markings were not recognised and the system steered the vehicle into the middle of the road.
- **Speed selection errors:** These occurred, in particular, when adapting the vehicle speed to the road trajectory in bends or at junctions, as well as on the concrete recognition of speed limits.
- **Contradictory braking and acceleration manoeuvres:** These were particularly frequent when the system lacked unambiguous reference points for controlling the vehicle speed. This was primarily observed in situations in which the preceding vehicle turned off or after exiting a roundabout.

The test drivers reported that some familiarisation time is needed in order to fully understand the system limits of the L2 driving functions. They also highlighted qualitative differences in the design of the cockpit displays that acted as the visual sources of information and that may influence both user-friendliness and the potential for distraction. Aspects such as information overload, the lack of clarity about the current system status (e.g. L2 system activity) and the positioning of the information (head-up display, central display or instrument cluster) were considered to be critical. Finally, the delayed notification of the deactivation of L2 functions, which was provided only at the very moment in which the functions were switched off, was considered to be a critical aspect. This behaviour repeatedly caught the test drivers unaware.











### 3.2. Development of the test scenarios

The 139 trigger events identified during the functionality tests in real traffic were assigned to the functional scenarios that had been identified during the literature search and that typically occur in real traffic. Table 3 presents the ten scenarios in which trigger events most frequently occurred, as well as the test drivers' subjective ratings of these events in real traffic.

The rating was performed based on the five criteria described by Schömig et al. [9] (clarity, transparency, comprehensibility, safety and criticality).

#### The most common trigger events

**Table 3** · Trigger events occurring during real drives on rural roads, listed by frequency of occurrence, Top 10

No.	Functional scenario	Icon	Number of trigger events	Frequency	Criticality
1	Same Trafficway / Opposite Direction Forward Impact-Head On Road Curve		24	17.3 %	5.4
2	Single Driver Left / Right Roadside Departure Curve		24	17.3 %	4.7
3	Speed Not Adapted to Road Features		19	13.7 %	5.1
4	Deceleration of System In A Trigger Event		12	8.6 %	3.6
5	Removal Speed Limit Not Detected, Set Speed Too Low		12	8.6 %	1.6
6	Speed Limit Sign Not Detected, Change of Set Speed Too Late		10	7.2 %	3.4
7	Same Trafficway/ Opposite Direction Forward Impact-Head On Road Straight		8	5.8 %	3.6
8	Free Travel Trigger Event, Overruling/ Self Deactivation		6	4.3 %	2.3
9	Target Vehicle Leaves Traffic Way, Ego Vehicle Brakes Inappropriately		5	3.6 %	2.8
10	Car-to-Car Rear Stationary CCRs		3	2.2 %	3.5

The three test scenarios for the functionality tests at the test site were chosen based on the results of the weighted sum analysis, in which all the identified functional scenarios identified in the literature search (including those listed in Table) were evaluated for their feasibility of implementation on the test track, frequency in real traffic, criticality and possibility of performing the handling rating.

Table 4 describes the chosen scenarios 1 to 3. Scenarios 1 and 2 correspond to the scenarios with the most frequent trigger events and those rated as being most safety-critical, as indicated in Table. Even though scenario 3 was not one of the scenarios most frequently observed in real traffic, it was accorded third place in the weighted sum analysis due to its high criticality. It also highlights the general high level of significance of this scenario for traffic safety. For example, accident analyses show that one in three of all accidents involving bicycles in Germany occur on rural roads and that a quarter of cyclist fatalities resulting from an accident occur on open roads. In these cases, it is usually the car that hits the bicycle [11].

**The functional scenarios were derived from the most frequent trigger events that were assessed as being the most critical to safety**

**Table 4** · Functional scenarios chosen for the functionality tests on the test track

Scenario	Explanation (Original English designation)	Explanation (German translation)
1	Same Trafficway / Opposite Direction Forward Impact-Head On Road Curve	Departure from lane in a right-hand bend with oncoming traffic
2	Single Driver Left / Right Roadside Departure Curve	Departure from lane at the edge of the carriageway in a left-hand bend
3	Cut-Out Fully Blocking	Evasive action in response to the sudden occurrence of an obstacle

The three functional scenarios from Table 4 were transposed into logical scenarios and finally into concrete scenarios by defining parameters in accordance with the methodology. The three concrete scenarios are illustrated and described in Table 5.

**Leaving the lane in a curve is an essential feature in the test scenarios**

**Table 5** · Description and illustration of the concrete scenarios

Concrete scenario	Description	Illustration
<b>1: Same Trafficway / Opposite Direction Forward Impact-Head On Road Curve</b>	<p>Ego vehicle follows target vehicle with advanced driver assistance function activated, circuit driven approx. 15 times (v = 60 km/h).</p> <p><b>Event:</b> Speed increased to 70 km/h (on the preceding straight section). The vehicle partly enters the lane for oncoming traffic. The point at which the ego vehicle meets the GVT vehicle is at the apex of the bend. Test subject reacts as a function of driver engagement.</p>	
<b>2: Single Driver Left / Right Roadside Departure Curve</b>	<p>Ego vehicle follows target vehicle with advanced driver assistance function activated, circuit driven approx. 15 times (v = 60 km/h).</p> <p><b>Event:</b> Speed increased to 75 km/h (on the preceding straight section). Vehicle partially leaves the lane. Test subject reacts as a function of driver engagement.</p>	
<b>3: Cut-Out Fully Blocking</b>	<p>Ego vehicle follows target vehicle with advanced driver assistance function activated, circuit driven approx. 15 times (v = 70 km/h).</p> <p><b>Event:</b> Bicycle travelling in lane, ACC vehicle reacts at the last moment. Test subject reacts as a function of driver engagement.</p>	

### 3.3. Functionality tests at the test site

The method employed by Schömig et al. [9] was used during the functionality tests at the test site to assess the quality of operating behaviour when activating the system (VLA), the quality of vehicle control in the test situation (the reaction to the behaviour of the system in response to an unexpected safety-critical event) and monitoring (which together constitute the VLR) and to obtain the test subjects' subjective perceptions in these safety-critical situations. Conclusions regarding driver engagement can be drawn based on the results for vehicle control and monitoring.

#### Rating of MMI and handling quality (VLA und VLR)

##### Rating of system activation (VLA)

The results show that the majority of the test subjects handled system activation either well or perfectly in all the vehicles, with the rating "Good handling" being the most frequently attributed (a graphical presentation of the results, including a breakdown into the four named categories, can be found in the research report no. 100 of the UDV).

#### Conclusions regarding driver engagement

It is possible to draw conclusions regarding driver engagement from the monitoring behaviour and handling behaviour in the test situation. Monitoring behaviour corresponded to a very large extent to the requirements of the systems (as indicated by the small number of hands-off warnings), suggesting an appropriate level of engagement during the drives. At the same time, the errors in handling behaviour, for example in the form of delayed reactions and lane departures, in particular in scenario 2, indicate that the test subjects were temporarily overloaded in the test situation, which could be due, at least theoretically, to a reduced level of engagement.

With the exception of the evidence of monitoring, it is not possible, on the basis of the available observational data, to draw any further-reaching or more detailed conclusions regarding the engagement of the test subjects during the drives or the nature and extent of their involvement by the systems.

## 4. Key takeaways and recommendations

### 4.1. Use of L2 driving functions on rural roads and vehicle model-specific conclusions

The evaluation of a total of 262 trigger events resulted in 139 driving situations on rural roads, from which ten functional scenarios were then derived and categorised. In addition to the frequency in percent, the average criticality value as subjectively rated by the test drivers was also specified for each trigger event.

The rating of the criticality of the scenarios reveals the following two key aspects for the evaluated advanced driver assistance functions in the three vehicles:

- **Lane-keeping/lateral control problems**, primarily in bends but also on straights with and without oncoming traffic, and
- **Inappropriate speed selection** for the various infrastructural elements of the route (e.g. entrance to built-up areas).

Lane-keeping errors were observed particularly frequently, with the vehicles tending to leave the carriageway or cross over into the lane for oncoming traffic. This occurred both on straights and in bends. The speed selection errors of the L2 driving function (e.g. in bends) and the Intelligent Speed Assist function were reflected by the fact that speed limits were not transferred correctly to the ACC or were transferred too late. There were also inappropriate braking and acceleration manoeuvres.

It was therefore found that when the L2 driving functions came up against their system limits, this was related first and foremost to the lane markings (lateral control) and speed selection (longitudinal control). National specificities were not taken into account here.

It is possible to derive the following insights and requirements regarding the technical and HMI-related configuration of the L2 driving functions on the basis of the evaluations of the functionality tests in real traffic and on the test track:

- **Combining hands-on monitoring with driver status monitoring**  
The test drives showed that considerably more than half of the test subjects were unable to handle the scenarios without errors. Modern L2 driving functions monitor the required contact with the steering wheel by means of capacitive sensors. Additional monitoring of the driver status on the basis of eye and head movements also seems advisable for vehicles with L2 driving functions.
- **The driving function should only provide moderate steering support**  
The functionality tests at the test site revealed configuration differences between the vehicles in terms of the involvement of the driver in the driving activity. To keep drivers in the loop at all times and give them the feeling of being involved in the act of driving, it is necessary for the lane-keeping element

of the L2 driving function to provide only moderate support, in line with the cooperative approach to driver assistance.

→ **Clearer cockpit display of activated L2 driving functions and standardisation of icons**

This would make it easier to see and understand the sometimes very small icons that light up and therefore simplify the handling of the system, in particular for drivers who frequently change vehicle or for beginner drivers. What is more, the use of a clear set of icons designed in the same way across all vehicles would reduce “mode confusion” and bring greater clarity.

→ **Systems should issue warnings when they approach their limits**

During the test drives in real traffic, the test drivers reported that it takes some time to get used to the system functionality and the associated system limits. An early, clearly comprehensible warning that the system is reaching its limits (e.g. lateral acceleration in bends) is required. This issue is an important consideration with regard to advanced driver assistance functions and has already been addressed in an earlier study [7].

→ **Avoidance of mode confusion between manual and advanced driver assistance functions**

Mode confusion was sometimes observed among the test subjects at the test site, because they assumed that they had handed over responsibility for driving to the system and were then surprised to have to intervene when a trigger event occurred. This is also a key aspect of advanced driver assistance functions [7].

The fact remains that none of the tested L2 systems is, in its current form, suitable for safe, continuous use on all types of rural road. This is because, on the one hand, the systems often failed to adequately address the infrastructural challenges encountered on rural roads (e.g. lane-keeping and speed adaptation) and, on the other, did not ensure that the driver was sufficiently involved in the driving activity (thereby maintaining driver engagement).

The answer to the question of whether L2 driving functions in general should be used on rural roads is therefore a clear “No”. L2 systems can only be used as successfully as they are on motorways on rural roads equipped with a high standard of infrastructure. The evaluated lateral and longitudinal control systems failed to exhibit continuous reliable functioning on rural roads with infrastructural deficiencies, as well as in the typically more complex traffic situations that arise on rural roads.

#### 4.2. Derivation and implementation of test scenarios for L2 driving functions on rural roads

The project successfully demonstrated that the safety-critical driving situations identified in real traffic can be transposed to test scenarios implemented on test tracks by adapting the parameters, such as bend radii or speeds, and using appropriate test targets.

The characteristics of the test scenarios (bend radii, speeds, markings) corresponded either to the functional scenarios identified during the first project phase

or to basic scenarios. It is therefore possible, in principle, to draw conclusions that are valid for all roads on the basis of the results observed in the tests.

The test scenarios that could be feasibly implemented and represented critical situations during L2 use on rural roads took the form of scenarios in which the vehicle risked leaving its lane, as well as scenarios in which the drivers had to react to an event of which they had not been informed. They are as follows (see Table):

→ **Test scenario 1:**

The ego vehicle follows a preceding target vehicle. Choosing an appropriate vehicle speed (49-78 km/h) and bend design (bend radius 50-243 m) causes the vehicle to leave its lane in a right-hand bend with oncoming traffic, thus requiring intervention on the part of the driver.

→ **Test scenario 2:**

The ego vehicle follows a preceding target vehicle. Choosing an appropriate vehicle speed (49-78 km/h) and bend design (bend radius 50-243 m) causes the vehicle to leave its lane in a left-hand bend, thus requiring intervention on the part of the driver.

→ **Test scenario 3:**

The ego vehicle follows a preceding target vehicle driving at a predefined speed. The target vehicle manoeuvres to avoid a cyclist without notification and gives the ego vehicle a clear view, thus requiring intervention on the part of the driver or AEB. A manoeuvre of this kind was also used by Schömig et al during the development of the handling rating.

### 4.3. Applicability of a method for evaluating driver engagement

No standardised method for evaluating driver engagement in complex traffic environments on rural roads is as yet currently available.

#### Application in real traffic

Using Schömig et al.'s method, it is possible to come to a comparative evaluation of drives involving different test vehicles and test scenarios. To use this method in complex traffic environments with varying speed limits, as are typically found on rural roads, it is necessary to adapt the observational variables. The variables used in the project are listed under the three categories: "Operating problems", "Vehicle control" and "Monitoring". Here, the method was adapted by adding variables that make it possible to address the question of the driver's understanding of their role (manual driving vs. assisted driving) in a more differentiated way and therefore prevent any distortion of the results. In the project, the method was not found to be a particularly sensitive way

- of measuring the test subject's understanding of their responsibility for the driving activity (mode confusion), or
- of getting the test subjects to deliberately push the systems to their limits.

### **Use on the test track and conclusions regarding driver engagement**

The selected test procedure and the general test setting chosen were suitable for implementation on the test track. The handling rating as a method for evaluating the MMI during the use of advanced driver assistance functions made it possible to draw indirect conclusions regarding driver engagement. This was done by recording the quality of the (motor) monitoring behaviour (“hands on wheel”) and the observed quality of vehicle control (i.e. how drivers react to unexpected events). These factors can provide an indication of whether driver engagement is appropriate or inadequate (e.g. vehicle-control problems such as “lane departure”).

It is, however, not possible to draw any specific conclusions regarding the nature and extent of driver involvement by the L2 systems based on the acquired data and the use of Schömig’s method. A further development of the method that permits a more detailed apprehension of the extent to which the system involves the driver would be welcome. This could, for example, include aspects such as gaze direction in order to come to further-reaching conclusions regarding driver engagement that go beyond merely the driver’s monitoring behaviour (e.g. hands-off warnings).

## 5. Requirements for future research

The results of this study show that the use of current L2 driving functions on rural roads can most certainly not be recommended. Although the L2 systems largely operate correctly on rural roads that are well-equipped with the necessary infrastructure, they can nevertheless not be used unrestrictedly because they are prone to performance errors. This finding results in at least two tasks for the future: First, it is necessary to determine whether the critical situations also lead to corresponding accidents. If they do, then the exact causes should be identified and eliminated. Second, it will be necessary to determine whether future L2 driving functions in accordance with UNECE R171 function more reliably both generally and on rural roads, in particular, and whether they continue to exhibit the shortcomings identified here. Furthermore, additional functionalities will make L2 driving functions more desirable, at least in terms of comfort. Driving without one's hands on the steering wheel (hands-off) is an important aspect here because it blurs the boundary with automated driving (L3) for the driver and raises the challenge of mode confusion to a new, critical level. However, functions that assist during lane changes must also be tested in practical use and may have to be reevaluated in their context of operation.

Another important research question relates to the investigation of the long-term effects of using L2 driving functions on driving behaviour and driver involvement in the driving activity. While the current study focused on immediate reactions, other studies have, for the first time, shown that the driver's behaviour changes when driving with activated L2 driving functions and that drivers often knowingly push the systems to their limits [12,13]. It will also be necessary to clarify the extent to which this behaviour leads to increased accident occurrence.

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**Gesamtverband der Deutschen Versicherungswirtschaft e. V. (GDV – German Insurance Association)**  
Wilhelmstraße 43 / 43 G, 10117 Berlin  
Postfach 08 02 64, 10002 Berlin  
Tel. 030 2020–5000, Fax 030 2020–6000  
[www.gdv.de](http://www.gdv.de), [berlin@gdv.de](mailto:berlin@gdv.de)