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# VDV Recommendation 191

07/2019

# Advanced Driver Assistance Systems (ADAS) for Tramcars for Avoidance of Collision with Obstacles Situated Directly on the Track

ADAS function level 1

**Overall revision**
Committee on Urban Rail Rolling Stock

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Committee on Urban Rail Rolling Stock

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# Preface

Nowadays, very different kinds of advanced driver assistance systems (ADAS) are available for all kinds of vehicles. In the last few years several VDV member companies have tested them in tramcars and light rail vehicles, especially in respect of avoidance of collision with obstacles situated directly on the track. Meanwhile, they have gained so much experience with the test operation of ADAS that it seemed meaningful to prepare this VDV Recommendation to support other VDV member companies with the introduction of such systems.

This VDV Recommendation is particularly intended to support the public transport companies operating tramways and light rail systems (street-running systems according to Section 2 of BOStrab (Section 4 (1) of PBefG)) by the preparation of the technical specifications, the homologation procedures (putting into service according to Section 62 of BOStrab) and the regulations governing the contractual acceptance of ADAS according to the German Civil Code (BGB) by the procurement of new vehicles or the retrofit of existing vehicles. However, it also includes recommendations on the introduction and operation of ADAS.

In this VDV Recommendation ADAS are systems used to avoid collision with obstacles situated directly on the track; these systems are called “ADAS function level 1” in this document. These ADAS have deliberately been so designed that they only detect and react on simple potential collision obstacles. It is the intention to start off a generic development of the ADAS just as in the automotive field.

It is already now obvious that it will be possible to integrate further ADAS functions, which will be defined as further function levels. It is the intention to prepare separate VDV Recommendations when these function levels have been exactly specified.

This VDV Recommendation does not include descriptions of the system architecture and the sensors to be applied. It is the intention to prepare a VDV Report on these subjects.

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*Translator's note:*
*In case of doubt or differences to the German version of this Recommendation the German version is valid.*

# Abbreviations

| | |
|---|---|
| ADAS | advanced driver assistance system |
| BGB | German Civil Code |
| BOStrab | German Federal Regulations on the Construction and Operation of Tramways |
| TAB | technical supervisory authority according to Section 5 of BOStrab and Section 54 (1) of PBefG |
| PBefG | Federal Law on Passenger Transport |
| Sifa | driver's safety device (§ 38 (2) of BOStrab) |

# 1 Introduction

*Note:*
*The term "tramcar", which is used in this document, also includes other kinds of in-street rail vehicles, e.g. light rail vehicles.*

When a tramcar collides with another tramcar, a motor vehicle or a trailer or a fixed obstacle, e.g. a buffer stop, the drivers, the passengers and perhaps also persons in their vicinity are in danger.

Accidents can occur for many reasons. A motor vehicle driver can e.g. turn left carelessly or illegally, a tramcar driver can be inattentive, distracted or dazzled, a person crossing the tracks can be inattentive or the rail vehicle can have a technical defect. Advanced driver assistance systems (ADAS) at function level 1 cannot fully cover these scenarios. The ADAS specified in this VDV Recommendation are to support drivers operating tramcars on sight in accordance with Section 49 (1) of BOStrab in such a way that an inattentive or distracted driver is warned about an imminent danger or so that it gets active itself so early that the tramcar is stopped in front of the obstacle or – at least – so that the collision speed is reduced considerably. The driver's alertness to the traffic shall not be affected by the ADAS. Moreover, stimulus satiation shall be avoided.

It is expressly pointed out that the ADAS described in this VDV Recommendation do not store the data obtained, which means that they can neither be used to investigate the cause of an accident nor to check the drivers' performance and behaviour.

At present, the following ADAS are being or are going to be used by the operation of tramcars driving on sight in accordance with Section 49 of BOStrab:

— system warning about a potential collision obstacle, e.g. a passer-by, directly in front of a stationary vehicle ("passers-by protection");

— system warning about a potential collision with a tramcar driving ahead of the tramcar, with a stationary tramcar in front of the tramcar or with a track closure in front of the tramcar ("collision alerter" as a pure warning system);

— system warning about a potential collision with a tramcar driving ahead of the tramcar, with a stationary tramcar in front of the tramcar or with a track closure in front of the tramcar; if necessary, with subsequent brake release ("collision alerter" as an intervening system).

# 2 General Conditions

## 2.1 Basic Rules for Driving on Sight / Legal Position for the Operation of an ADAS

According to § 49 (1) of BOStrab (“traffic control”) the driver is the person chiefly responsible for the avoidance of collisions when he/she is driving on sight. He/she detects potential collision obstacles, identifies the situation as imperilling and initiates either service braking or driver emergency braking in time. It is in no case the intention to annul this basic principle with the ADAS described in this document. It remains the principle of all technical implementations. Consequently, an ADAS is not a safety-relevant system.

*Note:*
*If line sections are equipped with command/control systems in accordance with Section 22 of BOStrab, it has to be determined whether the ADAS remains in operation in these sections and, if so, which functions it shall perform in this case.*

## 2.2 Objective of a ADAS function level 1 for Avoidance of Collision

A ADAS function level 1 merely has to support the driver when he/she is driving the tramcar on sight and shall draw his/her attention to potential collision obstacles in time. The optical and/or acoustic warning enables the driver to initiate braking earlier than he/she would probably have done without such an ADAS. In this way collisions can be avoided or lessened because the impact energy is reduced; the latter case reduces the severity and the consequences of unavoidable collisions.

As an additional step, an ADAS can also initiate braking when a tramcar is being operated on sight. In this case the braking rate and the suitable braking mode shall be determined at the planning stage.

The driver is and remains the key element when he/she is driving the tramcar on sight. He/she is still responsible for the avoidance of collisions. The ADAS is merely additional vehicle equipment, which assists the driver by the driving of the tramcar, i.e. by the detection of a hazardous situation.

## 2.3 Interface Partners

### 2.3.1 General

It is absolutely essential to involve all relevant interest groups in the introduction of an ADAS. Beside the operating manager according to BOStrab the following authorities, interest groups and departments of the public transport company have to be involved:

— operation department;

— vehicle technology and maintenance department;

— technical supervisory authority;

— data protection supervisor;

— works/staff council.

### 2.3.2 Operation Department (driving school, train service, control centre)

The operational processes of the ADAS technology shall be explained and it shall be made absolutely clear to everyone that the rules for driving on sight remain valid.

### 2.3.3 Vehicle Technology and Maintenance Department

It shall be ensured that the procedures and workshop equipment needed for the practical operation of the ADAS are available and that the basic physical principles of the ADAS are clearly understood.

### 2.3.4 Technical Supervisory Authority

Before the ADAS is put into service, the requirements shall be discussed with the technical supervisory authority. This aspect is especially important if the ADAS is to intervene in the brake control.

### 2.3.5 Data Protection Supervisor

If video cameras are to be used, the data protection supervisor shall be consulted about storage of video images, e.g. to develop or test the system. He/she might put forward further requirements, e.g. marking of the vehicles.

### 2.3.6 Works/Staff Council

The introduction and operation of an ADAS is a development of the driver's workplace towards assistance. Therefore, the drivers' representatives (works/staff council) shall be consulted when it is intended to introduce an ADAS. The early involvement of the council in compliance with the statutory provisions, a clear description of the improvements, the modifications and their effects as well as consideration of relevant tips increase the drivers' acceptance of the ADAS, which is absolutely essential for its introduction.

It is important that the works/staff council understands that the new technology is not introduced to monitor the drivers.

# 3 Requirements for an ADAS

## 3.1 Prerequisites for a ADAS function level 1

A ADAS function level 1 shall only be able to detect simple potential collision obstacles. At other function levels the ADAS might be able to detect more complex obstacles after appropriate software updates.

The ADAS is not a safety-relevant vehicle function. It only assists the drivers by their perception of potential collision obstacles. The BOStrab rules for driving on sight are not affected.

A ADAS function level 1 shall be able to detect the following potential collision obstacles situated directly on the track:

— the front or rear of a tramcar driving ahead of the tramcar as well as the front or rear of a stationary tramcar ahead of the tramcar;

— the front or rear of a motor vehicle;

— a track closure or a buffer stop.

To assess whether a potential collision obstacle is within the clearance of the tramcar, the ADAS has to monitor the track. Therefore, its reaction is a function of the distance to the potential obstacle and the speed of the tramcar. The ADAS can:

— warn the driver (preferably acoustic warning);

— initiate braking (i.e. intervene) if the driver does not react on the warning.

False positives cannot be excluded by the operation of an ADAS. Their frequency depends on the general conditions of the ADAS, e.g. kind of ADAS, infrastructure and vehicle type. Such false positives shall not affect the drivers' performance. Therefore, the public transport company and the manufacturer or supplier of the ADAS shall agree on their frequency.

## 3.2 Detection Area

The detection area of the ADAS is the track directly in front of the tramcar. In case of a straight in-street track the ADAS shall at least be able to detect a 30 m long track.

## 3.3 Detection Quality

The contractor and the customer shall agree on the project-specific detection quality, which can be demonstrated within the scope of a function verification pursuant to Section 640 of the BGB ("Acceptance"); see 4.3.

Operator-specific parameters, e.g. infrastructure, fitting in/on the vehicles and mode of operation, shall be considered.

The detection quality is tested both in a reproducible technical test and in a practical test within the operator's network; see Annex A. The test of the ADAS includes several scenarios.

To determine the detection quality, the test specimen specified in Annex B shall be used. This test specimen shall always be available on the operator's premises.

## 3.4 Ambient Conditions and Operating Conditions

### 3.4.1 General Operating Conditions

It shall be possible to operate the ADAS in in-street tramcars driving on sight up to a speed of 70 km/h.

Moreover, the ADAS can be applied by shunting and setting back tramcars at underground line sections or at turning points. As, however, the visibility can be restricted at these locations, the function of the ADAS might be restricted.

### 3.4.2 Ambient Conditions

The sensors shall not perceive more than an attentive driver perceives. If the visibility is restricted due to the weather or poor lighting, the driver shall reduce the speed of the tramcar. The ADAS can never compensate for the driver's perception deficits, if any.

Unfavourable ambient conditions or bad weather shall not lead to a significant increase in the number of false positives of the ADAS, but can restrict its functionality. If necessary, its sensitivity can be reduced.

### 3.4.3 Track Curves

The minimum track curve to be detected depends on the detection angle of the sensors, the distance between the sensor and the pivotal point of the first running gear as well as the lateral and horizonal offset of the fitting position at the front of the tramcar.

It should always be possible to fully detect a track curve radius of > 50 m, but in case of very narrow track curves the detection area can be less than 30 m.

*Note:*
*There are often more false positives in narrow track curves.*

### 3.4.4 Points

Camera-based ADAS shall be able to detect a point, but not its position. If it detects a point, it only has to be able to detect obstacles between the tramcar and the point centre. If there is an obstacle behind this point centre, the ADAS need not react although the obstacle is still within the warning threshold.

### 3.4.5 Tunnels

Often the lighting is insufficient along underground tracks (in tunnels and underpasses). In this case the ADAS may switch off automatically to avoid false positives.

#### 3.4.6 Suppression of the Warning if an Obstacle is Approached for Operational Reasons

If an obstacle is approached for operational reasons, e.g. if a stop is designed for two tramcars, if the tramcar is to be parked or if the track ends with a track closure, the following applies:

— If an initial warning has been confirmed and the approach speed has been sufficiently reduced, a further warning may be suppressed.

— If there is another tramcar ahead of the tramcar within the warning distance and if the driver has confirmed the initial warning, a further warning may be suppressed.

— If the tramcar is operated at a low speed, e.g. < 5 km/h, the warning should be completely suppressed to allow an intended approach journey without an ADAS reaction.

## 3.5 Fitting in the Tramcar

In principle, an ADAS consists of the following components:

— sensors detecting obstacles;

— control device with interfaces to the vehicle control.

Depending on the ADAS model, the following subcomponents can be fitted:

— DC/DC converter with electrical isolation;

— signal converter for the speed signal with electrical isolation;

— acoustic signal generator;

— optical signal generator;

— relay.

At present, optical sensors (camera(s) [video sensor] or LIDAR [laser]) and/or radar sensor(s) are applied. Due to their physical properties the detection rate is significantly influenced by the fitting conditions. Thus, e.g. the following has to be considered:

— by radar sensors: It can be problematic to fit such sensors under the GRP front apron e.g. due to the shielding of the radar.

— by camera systems: There has to be free sight, which means that the camera has to be fitted in the area of the windscreen covered by the windscreen wiper.

The main area to be monitored is the track in front of the tramcar. The sensors should be fitted on the front of the tramcar in accordance with the system manufacturer’s instructions. The driver’s field of view and the protection of pedestrians shall always have top priority.

Due to their efficiency range (field of view) the sensors shall be exactly directed towards the area to be monitored. Therefore, it has to be possible to adjust the sensors in their supports. This aspect also has to be considered by the maintenance (e.g. exchange of windscreens). The sensors shall be so robustly mounted that their positions cannot be unintentionally changed.

The mass and shielding concept shall be observed by the electrical installation of the components. If the mass (GND) of the components is connected with the frame, the components shall be so fitted that they are insulated towards the car body. If motor vehicles components are used, the electrical interfaces between the ADAS and the vehicle control shall be so designed that

there is no potential. Reaction due to interaction between the ADAS and the vehicle control shall always be avoided. The installations requirements specified in EN 50155 shall be observed.

## 3.6 Interfaces between the ADAS and the Tramcar

### 3.6.1 General

The absence of physical reactions shall be ensured and demonstrated for all interfaces between the ADAS and the tramcar to avoid unintended brake function reactions. Technical brake function reactions can occur for the following reasons:

— external influence, inclusive of power supply and electromagnetic compatibility (emission);

— hardware (electrical) connections;

— software connections;

— other functional connections.

To avoid such reactions, suitable decoupling components shall be applied. If appropriate, the principle of absence of reactions also applies to the technical integration of the ADAS functions into the software of the vehicle control.

The power supply unit shall be appropriately protected against short circuits. Moreover, an appropriate earthing/isolation concept shall be realised.

The cables between the vehicle equipment and the ADAS as well as the cables between the single ADAS components shall be able to carry the expected loads.

There shall be a sealed switch in the driver's cab, via which the driver can switch off the ADAS if it does not work properly. Deactivation of the ADAS need not be recorded by the tachograph.

The interfaces depend on the functions of the ADAS. The following distinction is made:

— warning ADAS: "passers-by protection" and "collision alerter" as a pure warning system;

— intervening ADAS: "collision alerter" as an intervening system.

### 3.6.2 Interfaces of a Warning ADAS

The following interfaces are needed for the basic collision avoidance function, i.e. for the pure warning of the driver without integration of the ADAS into the vehicle control, inclusive of the vehicle software (e.g. to minimise the homologation procedure or the retrofit of tramcars):

— Inputs:
  — power supply: DC 24 V;
  — speed signal, provided that it is not generated by the ADAS itself (*Note: Depending on the kind of speed signal in the vehicle, it might be necessary to determine a suitable interface to the ADAS.*);
  — signal for the driver's acknowledgement of the ADAS warning.

— Outputs:

  — output of the warning by connection to separate or existing acoustic and/or optical indicators, perhaps via the vehicle control;

  — diagnostic interface for the trouble shooting and for software updates, perhaps with integration into the vehicle diagnosis.

#### 3.6.3 Interfaces of an Intervening ADAS

The following interfaces are needed for the extension of the ADAS and for integration of the ADAS into the vehicle control to realise further collision avoidance functions:

— Inputs:

  — inputs listed in 3.6.2.

— Outputs:

  — signal releasing braking for further processing in the vehicle control;

  — outputs listed in 3.6.2.

## 3.7 ADAS Reactions

#### 3.7.1 General Mode of Operation

In principle, the ADAS provides information about potential obstacles (collision warning). This information can be passed on to the driver as an acoustic and/or optical warning. Moreover, braking can be released.

If the driver, who is responsible for the operation of the tramcar, finds that there was no reason for the warning or the braking or if he/she finds that the warning or the braking was too early (i.e. if the driver cannot see an obstacle or if it is far away), the driver shall be able to override the warning or the braking, respectively, by a simple operator control action. A suitable device shall be provided for this purpose. Alternatively, an existing device, e.g. the driver’s safety device or the power controller, can be used for this purpose.

#### 3.7.2 Warning Function

If the ADAS detects an obstacle in the danger zone, the driver is warned. An acoustic warning signal is recommended as experience has shown that the drivers prefer such a warning to an optical warning. Especially in case of a collision risk, the driver has to pay full attention to the traffic. Therefore, an optical warning is less practical. The acoustic warning shall be clearly perceptible and it should clearly differ from other acoustic warning signals. If the ADAS is integrated into a driver's safety device, the same sound may be used.

*Note:*
*It is possible to use haptic signals, but they have not been applied in an ADAS yet.*

If an ADAS is an intervening ADAS, there should be an acoustic warning before the tramcar is automatically braked.

As regards the period between the warning and the release of the brake the following shall be considered:

— It should be longer than a driver's usual response time so that he can override the ADAS if it has been triggered due to a false positive.

— The stopping distance should not be unreasonably extended by waiting for the driver's reaction.

When the driver has overridden the warning, the warning shall be switched off and the automatic braking shall be suppressed, if relevant.

Optionally, the warning bell can be triggered when the ADAS detects a collision risk. However, it has to be born in mind that the warning bell would then be triggered relatively often in certain areas, e.g. in pedestrian zones with many crossing pedestrians.

#### 3.7.3 Brake Function

##### 3.7.3.1 General

The ADAS can intervene in the brake control. This intervention can be triggered by hard-wired signals or by vehicle software. The hard-wired solution, which does not depend on the vehicle software, is especially advantageous when vehicles are to be retrofitted. The integration of the ADAS into the vehicle software is the obvious solution for new vehicles and allows more functions. Both solutions are explained in detail below in the form of examples.

##### 3.7.3.2 Braking Mode 1: Non-releasable Braking

A floating break contact of the ADAS is integrated into e.g. the existing hard-wired safety loop. If the ADAS is triggered after an adjustable period, e.g. 2 s, non-releasable braking (e.g. safety braking according to the Technical Rules for Braking) is triggered. When the ADAS has been triggered, an acoustic signal is output.

The driver can override the ADAS within a certain period, which begins when the acoustic signal has been output and ends when the brake is released, by acknowledging the signal (e.g. via the foot or hand button of the driver's safety device), which is often necessary in practice to be able to react to non-avoidable false positives.

##### 3.7.3.3 Braking Mode 2: Releasable Braking

In case of releasable braking the braking is initiated via the software of the vehicle control after a certain delay, which can be individually defined. The tramcar is braked till it stands still or the braking stops automatically because the possible collision obstacle has disappeared.

If the driver finds that there was no reason for the warning or the braking, he/she can always easily stop the warning or the braking (e.g. by acknowledgement of the warning or defined actuation of the power controller).

## 3.8 Need for Operational Regulations

#### 3.8.1 Driver Training

The drivers shall be trained to handle the ADAS correctly. Theoretical and practical training has proved its worth, especially in respect of the various vehicle types. In practice, mentor-supported training has turned out to be successful. In this case an ADAS-trained driver or driving instructor

accompanies the driver on the job and explains how the ADAS functions. After this training the new technology is often fully accepted by the drivers.

### 3.8.2 Instructions of the Handling of the ADAS during the Operation

According to BOStrab the operating manager shall specify the operational handling of the ADAS in instructions. The following shall always be included in these instructions:

— operation and handling of the ADAS;

— observance of the rules for driving on sight;

— behaviour if the ADAS fails;

— operational peculiarities.

# 4 System Verification

## 4.1 General

Distinction is made between the putting into service according to Section 62 of BOStrab and the acceptance according to Section 640 of the BGB.

## 4.2 Putting into Service according to BOStrab

### 4.2.1 General

Section 62 of BOStrab regulates the official acceptance of putting technical installations and rail vehicles into service.

Section 62 (1) of BOStrab says:
*Unless it is merely the intention to determine the suitability of new or modified technical installations and vehicles, such installations and vehicles may only be operated when the technical supervisory authority has accepted that they are put into service. This rule only applies to modifications of technical installations and rail vehicles that can affect the operational reliability.*

As stated in 2.1 and 3.1, an ADAS is not a safety-relevant system. Consequently, the fitting of an ADAS on a tramcar is not a modification that affects the operational reliability.

### 4.2.2 Tests

#### 4.2.2.1 General

Distinction is made between type tests and routine tests.

#### 4.2.2.2 Type Test

Before the first ADAS-equipped tramcar of a series is put into service, a type test shall be performed to demonstrate that the ADAS functions properly. This rule applies both to new tramcars equipped with ADAS right from the beginning and to existing tramcars retrofitted with ADAS.

The type test includes the following:

- testing of the ADAS (see Annex A);
- testing of the new software functions of the vehicle control, inclusive of demonstration of absence of reactions on the vehicle functions, i.e. at least the following is tested:
  - testing the absence of reactions on other vehicle functions;
  - testing absence of reactions on other brake modes;
- demonstration of the following functions:
  - overriding of the ADAS warning and ADAS braking by the driver in the “driving” and “braking” modes;

— overriding of the ADAS braking by braking with a driver's safety device;

— overriding of the ADAS braking by driver emergency braking;

— overriding of the ADAS braking by an electro-magnetic rail brake;

— overriding of the ADAS braking by passenger emergency braking;

— overriding of the ADAS braking by safety braking.

Each driver's cab of a dual mode tramcar shall be tested.

#### 4.2.2.3 Routine Test

A routine test shall be performed on each further tramcar of a series. The manufacturer shall provide a relevant declaration of conformity. The functions are to be tested to a certain degree, upon which the manufacturer, the operator and the technical supervisory authority shall agree.

## 4.3 Verification of the Function according to Section 640 of the BGB

By the acceptance of the ADAS according to Section 640 of the BGB it is tested whether the detection quality objectives of the operator and the supplier of the ADAS are reached. The test is a type test and is to verify the functions. The acceptance test consists of two steps and includes several tests:

— step 1: reproducible technical test on a test site, within the scope of which a tramcar approaches and passes one or several test specimens;

— step 2: practical test on a specific line within the operator's network.

The customer and the contractor shall agree on a test specification. The ADAS shall be accepted on the basis of the specified application.

# 5 Maintenance according to Section § 57 of BOStrab

## 5.1 Testing of the Reliability of the ADAS

The maintenance plan shall specify that the ADAS shall be tested for its reliability at regular intervals.

## 5.2 Testing after Corrective Maintenance

The ADAS function shall be tested after corrective maintenance. The kind and scope of tests depends on the scope of the corrective maintenance.

## 5.3 Improvement of the ADAS Properties

As the ADAS, especially its hardware, is continuously further developed, it is important to leave open the possibility of introducing a new ADAS generation within the scope of an inspection.

Often hardware components are obsolete already after a few years. Therefore, they should be on stock as an ADAS can fail, e.g. due to an accident.

It should always be possible to update the software, if necessary. If possible, the software should be updated when a new hardware generation is introduced.

# 6 Adaptation of the Parameters

## 6.1 General

Several parameters of the ADAS can be adapted:

— parameters influencing the detection of obstacles.

  These parameters can only be adapted by the manufacturer of the ADAS.

— parameters considering the fitting position of the components in/on the tramcar.

  To be able to calculate the relative distance between an obstacle and a tramcar, the ADAS has to know e.g. the following parameters:

  — fitting height, horizontal offset as well as distance between the pivotal point of the first running gear and the sensor components;

  — width of the tramcar, which can vary for the various vehicle types, and gauge.

  These parameters are determined once when the ADAS is integrated into the tramcar and should not be modified during the life of the tramcar.

— parameters concerning the reaction of the tramcar:

  e.g. the distance and speed threshold values for the triggering of a warning or the braking. These parameters may be modified by the manufacturer of the ADAS and by authorised staff of the operator.

## 6.2 Parametrisation of the ADAS

### 6.2.1 General

Distinction is made between system parameters and, if any, vehicle control parameters.

It is once again stressed that certain parameters may only be entered and/or modified by authorised staff.

### 6.2.2 System Parameters

System parameters, which may only be modified by authorised staff of the manufacturer of the ADAS to adapt the ADAS to the characteristics of the tramcar:

— gauge;

— distance between the pivotal point of the first running gear and the sensor components;

— deceleration possibilities of the brake system;

— distance to the obstacle at which a warning is triggered as a function of the speed.

### 6.2.3 Vehicle Control Parameters

Vehicle control parameters, which may only be modified by authorised maintenance staff:

— driver’s response time (, which is used by the vehicle control as a reaction to a warning signal);

— braking rate;

— general switching on and off of the ADAS, perhaps with differentiation between “off”, “only warning” and “warning and braking”.

# Annex A: Testing the Detection Quality

The detection quality is determined under the given ambient conditions. The below-mentioned test environment should be provided. Moreover, it might be necessary to consider system-specific conditions by the acceptance. The manufacturer of the ADAS shall be informed accordingly. The test specimen shall fulfil the requirements specified in Annex B.

Test environment:

— straight, level track in a closed area;

— the test track shall be so long that the tramcar can accelerate to the required acceptance speed, that the specified detection range is observed and that there is a reserve of at least 100 m;

— closed formation, no sleepers, no plants in the track bed;

— no points on the test track;

— good contrast between the rails and the ground (rails brighter than the ground);

— no metal sheets on the ground up to 5 m in front of the test specimen in the direction of travel;

— no moving objects in the vicinity of the test specimen;

— the test specimen shall be positioned as a single obstacle in the detection area and not in a radial distance to overhead contact line poles, guard rails, concrete pillars, vehicles (cars, trucks, rail vehicles) and buildings;

— for safety reasons there shall be a “secured area” behind and around the test specimen to consider a collision, if any, with the test specimen during the test;

— overhead contact line poles, fences and the like shall be at least 3 m from the top of rail;

— no roofing;

— no infrastructure buildings/structures in the immediate vicinity of the obstacle.

Ambient conditions:

— in the daytime at normal daylight;

— cloudy or sunny;

— no direct solar radiation into the tramcar from the front;

— no precipitation;

— clear sight of at least 300 m.

The detection quality can only be tested when the ADAS has been parameterised in accordance with the operator’s data. Depending on the functions of the ADAS, it might be necessary to adapt parameters like detection distance, size of obstacle and detection duration.

The operator and the supplier of the ADAS shall agree on the exact scope of testing in advance in consideration of the characteristics of the ADAS.

The scope of testing shall include at least the following tests, which exclusively aims at warning the driver:

— approaching the test specimen.

  The test specimen is situated directly on the track. The speed of the tramcar ranges from low to average speeds (10 – 30 km/h) and is increased at steps of 5 km/h. The warning should be output at the expected time. It might be necessary to manually initiate or support braking to avoid a collision with the test specimen.

  The test shall be performed three times at each speed. Two of these three tests at each speed shall be passed.

— passing the test specimen at a speed of 20 km/h.

  The test specimen is 0.5 m out of the clearance of the tramcar on the straight track. The driver should not be warned about the obstacle.

  The test shall be performed three times. Two of these three tests shall be passed.

If braking is released automatically, the scope of testing shall also include the following test:

— approaching the test specimen.

  The test specimen is situated directly on the track. This test should be performed at a speed of 15 km/h. Collision with the test specimen should be avoided without the driver's manual braking support.

  The test shall be performed three times. Two of these three tests shall be passed.

Moreover, a practical test shall be performed:

— this test is passed if a certain number of false positives, on which the operator and the manufacturer have agreed beforehand, is not exceeded on a specific test line within the operator's network.

# Annex B: Test Specimens for the Detection of Obstacles

The test specimens should be so designed that they are easy to transport and store. Moreover, they should be so designed that the tramcar is not damaged in case of a collision with a test specimen.

Object properties/information sources that merely identify the obstacle as an obstacle to the ADAS (active transmission sources, artificial optical patterns etc.) are not allowed.

Examples of obstacles (design of uniform test specimens):

— optical systems:

  obstacles that can be optically detected, e.g. a tarpaulin on which a car is printed (width x height: approx. 1.5 m x 1.5 m); the colours of the obstacle should clearly contrast with the background.

— radar system:

  obstacles reflecting radar beams, i.e. radar mirrors, which are so arranged that they realistically image a vehicle, e.g. in the form of three radar mirrors.

# Legislative Rules – Acts, Regulations and Directives

| | |
|---|---|
| BGB | German Civil Code |
| BOStrab | German Federal Regulations on the Construction and Operation of Tramways |
| PBefG | Federal Law on Passenger Transport |

# Technical Rules – Standards and Recommendations

| | |
|---|---|
| EN 50126 | Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) |
| EN 50128 | Railway applications - Communication, signalling and processing systems - Software for railway control and protection systems |
| EN 50129 | Railway applications - Communication, signalling and processing systems - Safety related electronic systems for signalling |
| EN 50129 supplement 1 | Railway applications - Communication, signalling and processing systems - Application Guide for EN 50129 - Part 1: Cross-acceptance |
| EN 50129 corrigendum 1 | Railway applications - Communication, signalling and processing systems - Safety related electronic systems for Signalling - Corrigendum to EN 50129 |
| EN 50155 | Railway applications - Rolling stock - Electronic equipment |
| VDV Recommendation 161/1 | Safety Requirements for the Electrical Equipment of Light Rail and Metro Vehicles - Part 1: Basic Principles |
| VDV Recommendation 161/2 | Safety Requirements for the Electrical Equipment of Light Rail and Metro Vehicles - Part 2: Safety Integrity Requirements for Vehicle-related Electrical/Electronic/Programmable Electronic Protective Functions (E/E/PE) |
| VDV Report 1520 | State of the Art of Driver Assistance Systems for Collision Avoidance for Tramcars and Light Rail Vehicles |

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