AUTOMATED AND AUTONOMOUS VEHICLES - SAFETY, APPROVAL, SOCIAL BENEFITS AND FEARS OF INTRODUCING AUTOMATIC DRIVING SYSTEMS

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Abstract:

The paper discusses the details of the work of automation systems for motor vehicles and their methods of testing. The requirements of the new UN Regulation No. 157 were presented as a tool for conducting the type-approval of automated vehicles in the field of the Automated Lane Keeping System (ALKS). The most important requirements and methods of testing ALKS systems for the vehicle type-approval are described. Evaluation of the advantages and disadvantages as well as the effects and social concerns of the implementation of such systems in relation to the road safety, has been carried out.

Keywords:

autonomous vehicles, automated vehicles, road safety, social evaluation

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1. Introduction

Road traffic safety (RS) is still a very important issue from the point of view of socio-economic development. Reducing the number of accidents and collisions is aimed at achieving social and material benefits. This stage can be carried out in many ways - both by introducing passive safety elements, road infrastructure elements, as well as by using vehicle monitoring and response systems used in partially (automated vehicles) and fully autonomous cars. However, it should be emphasized that introducing autonomous or automated vehicles for the road use has both benefits and risks. The research results of many manufacturers of systems for automatic driving vehicles indicate that at the current technological stage, this type of product requires refinement. In addition, there is a need to develop test programs, including type-approval ones, in order to allow the use of vehicles equipped with autonomous or automatic driving functions. Type-approval and preparation of requirements for vehicles equipped with such systems is one of the key activities at the United Nations and the European Commission [1]. In the case of autonomous and automated vehicles, the development of type-approval requirements is not an easy task. On the one hand, it is not possible to recreate all possible scenarios of situations that may arise on the road. On the other hand, the strict specification of the test situations aimed at obtaining repeatability of the test results in various research units will result in the fact that the algorithms developed in vehicles will be optimized for these specific situations.

In the case of vehicles equipped with automatic driving systems, tests and road cases show that it is still an underdeveloped and unreliable technology [11]. Manufacturers strive to have automated vehicles in their commercial offer, but the examples show that technical requirements should be developed for automatic driving systems that will ensure safe travel.

In addition to the revolution in the field of technical requirements for vehicles, changes in the road traffic regulations and driver training will be required. Automated vehicles will communicate with the driver differently and expect completely different reactions from the driver. This, in turn, will require changes to the law and the way drivers are trained to „use" autonomous or automated vehicles safely. Manufacturers are also responsible for the operation of automatic driving systems and for securing them against external interference.

2. Vehicle type-approval - changes in the regulations from September 2020

Until 2007, all countries used, the so-called, national vehicle type-approvals. Legal requirements were developed based on the European regulations and implemented into national law. Work has been carried out for many years to harmonize the provisions on the type-approval of motor vehicles and the trailers for these vehicles in the European Union. In 2007, Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the type-approval of motor vehicles and their trailers, as well as systems, components and separate technical units intended for these vehicles, was adopted. In 2018, the Framework Regulation (EU) 2018/858 entered into force, which will fully replace Directive 2007/46/EC and exactly, like the Directive, applies to the M, N, O categories vehicles and replaces the current Framework Directive, which expired on the 1 September 2020 in terms of issuing type-approval certificates for **the new vehicle types (i.e. types approved for the first time)**.

2.1. Type-approval of autonomous or automated vehicles with the exception of new technologies

Before developing the regulations authorizing the use of automatic driving systems, it is possible to type-approve vehicles equipped with innovative systems, new technology or concepts, such as e.g. automated steering systems, based on the exemptions for EC type-approval. Without a doubt, automation of the steering function represents such a technology. The manufacturer may apply for EC type-approval with respect to the type of vehicle, system, component or separate technical unit incorporating new technologies or new concepts which are not in line with one or more regulatory acts. The approval authority shall grant an EC type-approval where the vehicle manufacturer has identified the reasons why the use of new technologies or new concepts has the result of non-compliance with the regulatory acts. The manufacturer must determine the safety and environmental impact of this new technology or new concepts and the measures taken to ensure the level of safety and environmental protection at least equivalent to the requirements for which the exemption is requested. It should be emphasized that granting of EU type-approvals representing exemption for the new technologies or new concepts, requires authorization from the European Commission. The European Commission adopts implementation acts in order to decide whether to grant a permit. A national type-approval authority may grant a provisional EC type-approval valid only on the territory of the Member State of that type-approval authority.

3. Degrees of vehicle automation / autonomy

Dynamic driving task (DDT) includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to the events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic aspect (determining destinations and waypoints) of the driving task.

The vehicle autonomy classification is mainly based on the SAE standard [2] and the following degrees of vehicle automation are distinguished [10]:
Level 0 - no automation. The driver is responsible for all aspects of driving, even assisted by warning or intervention systems, controlling movement in all driving directions;
Level 1 - driver support through the steering or steering assistance system using information about the driving environment and expecting the driver to perform all other Dynamic Driving Tasks (DDT);

Level 2 - partial automation. This means that the vehicle performs specific manoeuvres in specific conditions controlled by one or more steering assistance systems for both steering and acceleration/deceleration using information about the driving environment and with the expectation that the driver will perform all other DDT tasks;
Level 3 - conditional automation. It is possible, under the specific conditions of the driving mode, and the automated driving system controlling all aspects of the DDT task, with the expectation that the driver will respond appropriately to the request for intervention;
Level 4 - high automation. Under specific driving conditions, it enables the automated driving system to control the vehicle in all aspects of the DDT task without expecting the driver to respond appropriately to a request for intervention;
Level 5 - full automation (autonomus). Preparation for all DDT events in all road and environmental conditions.

In the informal document WP.29-175-20 submitted to the World Forum for Harmonization of Vehicle Regulations (WP.29), autonomous vehicles are classified according to the degree of automation. According to these provisions, **an automated vehicle is a vehicle equipped with a system that is designed to perform continuously the driving task, under certain circumstances. The driving task may be performed under the supervision of the driver or may be performed unsupervised, depending on the category of automation. A vehicle equipped with an Automatically Commanded Steering Function (ACSF) is classified as an automatic vehicle.**
However, vehicles equipped with other systems which, even if they change the path of the vehicle, such as ESC (Electronic Stability Control) or AEBS (Advanced Emergency Braking System), cannot be classified as automatic vehicles because the functions of these systems are not intended to perform the continuous driving task [3].

4. Automatic Lane Keeping System (ALKS)

The GRVA Working Group on Autonomous/Automatic and Connected Vehicles at the United Nations in Geneva. GRVA is an expert group operating and falling under WP.29. In 2018-2020, GRVA developed technical requirements for the automated driving [5], which were submitted for consideration by the World Forum for Harmonization of Vehicle Regulations (WP.29). The system was named ALKS (Automatic Lane Keeping System) and belongs to the group of ACSF systems. The guidelines developed in the form of the UN Regulations were positively considered and approved at the 181 session in June 2020. WP.29 approved the document ECE/TRANS/WP.29/2020/81 [4] which is a proposal of the new UN Regulation No. 157 on uniform regulations concerning the type-approval of vehicles with regard to an automated lane-keeping system. The intention of the new UN Regulations is to establish uniform rules for the type-approval of vehicles with regard to Automatic Lane Keeping Systems (ALKS). The system controls the lateral and longitudinal movement of the vehicle for a longer time than current systems in vehicles, used only for short-term vehicle path correction. **ALKS is a system that allows driving without the participation of the driver, a system that controls the vehicle**.
The system has limitations in terms of use and activation, it is intended only for passenger cars and its activation is possible only under certain road conditions. Activation of the system is possible only on the roads where pedestrians and cyclists are forbidden and there are no intersections, and traffic in the opposite direction is separated from the safety zone. The maximum speed at which the vehicle can travel while the system is operating is 60 km/h.
When ALKS is activated and carries out the driving task for the driver, the driver can always take control of the vehicle. UN Regulation No.157 also lays down the requirements for the safe driving of the vehicle by the system, the transfer of control to the driver, and in the event of the driver not responding to the request to take control, stopping the vehicle - a Minimum Risk Manoeuvre (MRM).
As part of the test scenarios, ALKS studies are planned based on the previously developed so-called concept of a 3-pillar approach to testing automated and autonomous vehicles. Accordingly, the systems are verified in 3 areas:
Audit and evaluation in the form of verification of the safety concept, including the reaction of the system to faults in any control unit. As part of these tests, the Type- approval Authority checks that these tests cover aspects that may affect the vehicle control and user information (HMI), e.g. driver takeover scenarios. As part of the activities, the authorities also verify the operation of the simulation tools and mathematical models used by the manufacturer to verify the correct operation of ALKS.
Physical tests are performed for difficult scenarios on the test track or under real conditions. Manufacturers must demonstrate the scope and simulation tool for a given scenario. As part of the validation of simulation tools, tests are carried out in order to correlate the simulation result with the result of physical tests.
Real-world test drive conducted by test institutes as part of the verification and testing process, the Type-approval Authority checks the overall behaviour of the system in real driving conditions, including, in particular, the compliance of the system with the road traffic regulations. As part of the tests, critical scenarios are also introduced and the characteristics of the decision-making process are checked. A situation is also introduced in which the system should request the driver to take control of the vehicle.
The system evaluation can only be carried out by auditors with the necessary technical and administrative knowledge for such purposes. In particular, they should be competent as auditors in terms of ISO 26262-2018 (Functional Safety - Road Vehicles) [6] and ISO / PAS 21448 (Safety of the Intended Functionality of Road Vehicles) [7]. Competence should be demonstrated by an appropriate qualification or other equivalent training.

5. Detailed type-approval requirements for ALKS

The activated ALKS should perform DDT, managing all situations, including possible accidents, without taking undue risk to the vehicle, passengers or other road users [4]. An activated system should not cause any collisions that are predictable and avoidable. The system is designed to safely avoid a collision without causing another one. ALKS must perform the driving task in accordance with the road traffic regulations. The system should have control of driver assistance systems (e.g. activation of windshield defogging systems, activation of vehicle wipers and exterior lights). The driver can manually control the devices at any time. The system is obligatorily equipped with a diagnostic system and performs a self-test in order to confirm the operation of the system, which involves checking the operation of electronic systems. Checking the sensors involves detecting the object from the distance declared by the manufacturer. Until the object is not detected, the system remains in the diagnostic mode [4].
The request to take control must not endanger the safety of the vehicle's passengers or other road users. In the event that the driver does not take control of the DDT during the request, ALKS should perform a minimum risk manoeuvre (MRM). When performing MRM, the system minimizes risks to the safety of vehicle occupants and other road users. This manoeuvre involves decelerating the vehicle to a halt, with a delay not exceeding 4 m/s2, and turning on the hazard lights. The stop is to be made in the lane and, in the event of no lane, along the intended path.
ALKS must adapt the vehicle speed to the infrastructure and external conditions (e.g. small cornering radii, unfavourable weather). The activated system detects the distance to the next vehicle ahead and adjusts the vehicle speed to avoid a collision. During operation, the system adjusts the distance from the vehicle in front on the same lane so that it is equal to or greater than the minimum distance. The minimum distance for speeds up to 7 km/h is 2 m and for a speed of 60 km/h 26.7 m. Where the minimum distance between the vehicles cannot be temporarily kept due to (e.g. the vehicle is entering the lane or braking in front of the vehicle) the vehicle adjusts the distance without hard braking. If such a situation requires a sudden reaction, the vehicle will perform the so-called emergency manoeuvre (EM). The emergency manoeuvre mode is activated if, in order to avoid a collision, braking with a deceleration greater than 5 m/s2 [4] is required.
The ALKS system, although it can only be used on the roads where pedestrian traffic is forbidden, must detect and avoid collisions with pedestrians in the entire speed range provided for ALKS. The maximum value of the speed at which a pedestrian moves was set at 5 km/h. In order to avoid a collision, the system can also use an obstacle avoidance manoeuvre. During this manoeuvre, the vehicle must not cross the road lane. After performing the avoidance manoeuvre, the vehicle should return to normal driving [4].
An activated ALKS must recognize all situations in which it must delegate steering to the driver. It should be safe to initiate a request to take control by a driver. In case of foreseeable situations that would prevent ALKS from continuing to work, the request to take control should be signalled early enough to allow time for a minimal risk manoeuvre in case the driver does not take control of the vehicle. In the event of unforeseeable situations, a request to take control of the vehicle is immediately signalled to the driver. Information that the driver has taken over control is also signalled immediately in the event of any failure affecting the operation of the system [4].
In the driver's takeover phase, the ALKS must be operational and may reduce the speed of the vehicle to ensure safety. Must not stop the vehicle,

unless required by the traffic situation. After stopping, the vehicle may remain in this state and must switch on the hazard flashers [4] within 5 seconds.
If the driver does not respond to the request to take control, but only deactivates the system, ALKS will initiate a minimum risk manoeuvre (MRM). In the event of a serious system or vehicle failure, the MRM may be started immediately. The manufacturer must declare the types of major vehicle breakdowns and ALKS major breakdowns that will trigger an immediate MRM initiation. The minimum risk manoeuvre must bring the vehicle to a halt, unless the system is disabled by the driver during the manoeuvre. The minimum risk manoeuvre may only be interrupted after the system has been switched off or the vehicle has stopped. The system must be deactivated at the end of each minimum risk manoeuvre. The hazard lights remain on unless they are manually turned off and the vehicle cannot start automatically when stopped in ALKS mode. Only the driver can move the vehicle [4].

5.1. Features and situations to be evaluated during type-approval tests of vehicles equipped with ALKS

Critical scenarios are anticipated as part of the testing of automated or autonomous driving systems. In the case of ALKS, 3 such traffic-critical scenarios are envisaged. ALKS's ability to avoid a collision is to be comparable to that of a typical driver. Therefore, the ALKS system should not be required to avoid collisions in the entire range of vehicle motion parameters, such as: vehicle speed with ALKS, lateral speed of the disruptive vehicle, relative vehicles speed. Different targets are used in the research. The target to be used in the vehicle detection tests must be a series M or N category vehicle for mass production or alternatively a so-called „soft target" representative of the vehicle in terms of its identification characteristics applicable to the sensor system of the tested ALKS in accordance with ISO 19206-3: 2018. The target used in the test of two-wheeled motor vehicles is a test device complying with the ISO CD 19206-5 standard or a category L3 motorcycle type-approved, series-produced, with an engine capacity not exceeding 600 cm3. The target used in pedestrian detection tests shall be a „soft articulated target" and represent of the human characteristics applicable to the sensor system of the tested AEBS in accordance with ISO 19206-2: 2018.
Before carrying out the type-approval tests, the manufacturer shall declare the boundary conditions of the system operation to the technical service. The technical service shall define different combinations of test parameters (e.g. ALKS vehicle speed, target type and offset, lane curvature) to cover scenarios where the system should avoid collisions as well as those where collision avoidance is not possible, where appropriate. The following tests and critical scenarios were introduced as part of the research [4].

The lane-keeping test should demonstrate that the vehicle with ALKS does not stray out of the lane and maintains a stable position in the lane throughout the speed range and at various curvatures within system operation limits. The test must be performed for a minimum of 5 minutes with a target of a passenger car, a 2 wheeled motorcycle and another vehicle in the adjacent lane.
Collision avoidance test with another road user or object blocking the lane. The test should demonstrate that the ALKS avoids a collision with a stationary vehicle, other road user or a fully or partially blocked lane up to the maximum specified system speed. This test should be performed with a stationary passenger car; a two-wheeled motorcycle, a stationary pedestrian target, and moving objects taking into account a pedestrian crossing the lane at a speed of 5 km/h. In addition, with the target representing the blocked lane and partially in the lane. The test should also be performed with a number of successive obstacles blocking the lane (i.e. in the following order: vehicle - motorcycle – car). The tests should be performed on a curved stretch of the road.

The car follow-up test should show that the ALKS is capable of maintaining and resume the required safe distance from the vehicle in front, and is able to avoid hitting the vehicle in front, when this slows down with various decelerations. This test must be performed over the entire speed range foreseen for the ALKS and using the target as a passenger car as well as the motorcycle as lead vehicle for steady and variable speeds of the leading vehicle (e.g. according to a realistic speed profile from an existing driving database). The test shall be performed on a straight and curved road sections and for different lateral positions of the leading vehicle in the lane. The test must also take into account a sharp reduction in the speed of the leading vehicle, with an average fully developed deceleration of at least 6 m/s2 until the vehicle comes to a stop. An example of such a test is shown in Fig. 1.

Test of changing the lane of another vehicle for the lane on which the vehicle with ALKS is travelling. During this test, it is checked whether the ALKS is capable of avoiding collision with the vehicle entering the lane of the vehicle with ALKS, up to the critical conditions of the lane entering manoeuvre. Critical conditions are determined according to a Time To Collision (TTC) using the longitudinal distance between the rearmost point

Fig. 1. Scenario of following a leading vehicle [4]

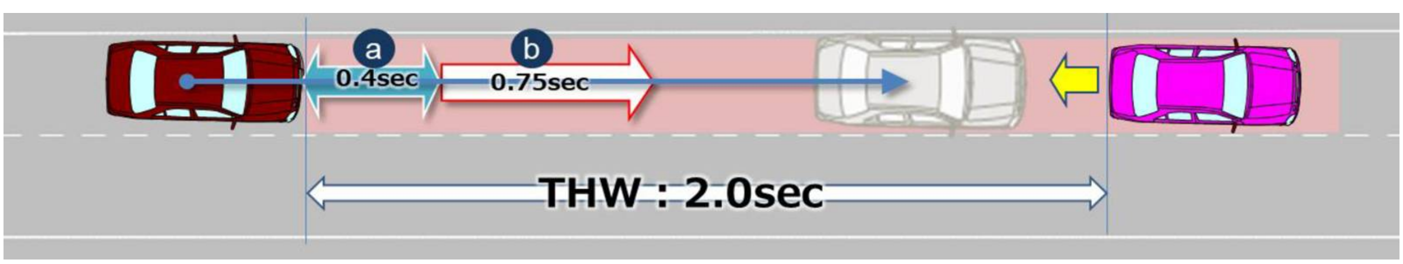
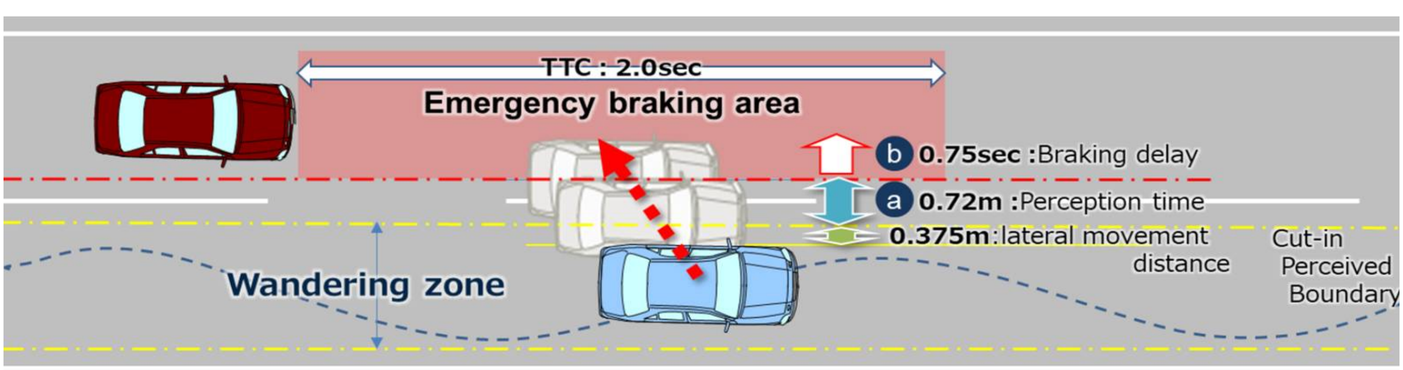


Fig. 2. Scenario of the vehicle entering the lane in front of the vehicle with ALKS [4]



on the vehicle in front and the foremost point of the vehicle with ALKS. The TTC also takes into account the lateral speed of the entering vehicle and the longitudinal speed of the vehicle entering the lane (Cut-in scenario) (Fig. 2). This test shall be performed for different TTCs, distance and speed values for the lane entry manoeuvre, including both avoidable and unavoidable collision situations, and the tests of the vehicle entering the lane with other vehicles are travelling at a constant longitudinal speed, accelerating and decelerating. Additionally, also for different lateral speeds and lateral accelerations of the entering vehicle. Tests should be conducted with targets in the form of cars and motorbikes.

Test for detection and response to a stationary obstacle after lane changing by the vehicle in front. In this test, it is checked whether ALKS is capable of avoiding collision with an obstacle in the form of a stationary vehicle, another road user or an obstacle in the traffic lane. The danger is detectable after the vehicle in front has avoided a collision by an evasive manoeuvre. The test is performed with a stationary passenger car, motorcycle, pedestrian and stationary object located in the centre of the lane, and with multiple successive obstacles blocking the lane. The situation is presented in Fig 3.

Fig. 3. Scenario of leaving the lane by the vehicle in front of the vehicle with ALKS [4]

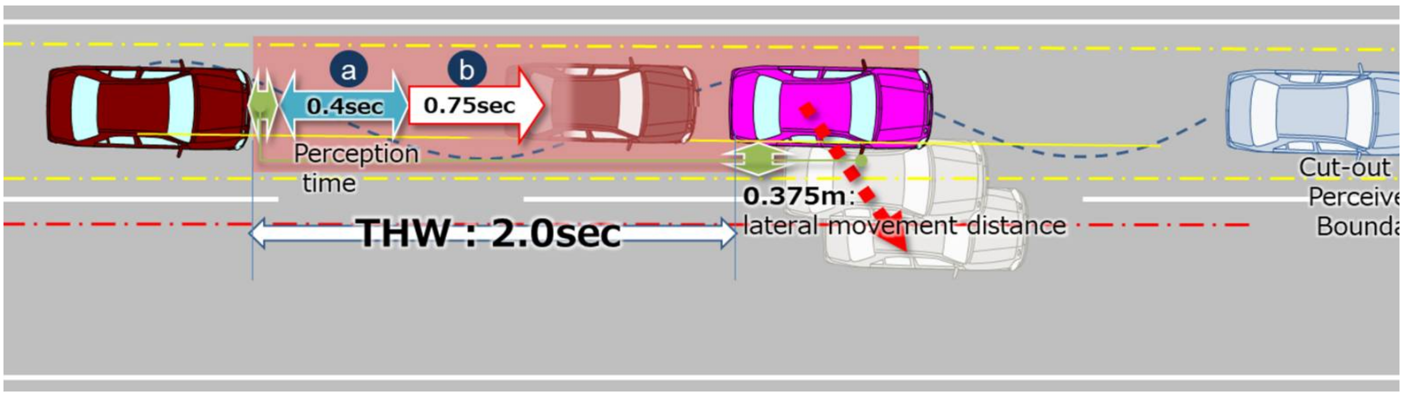
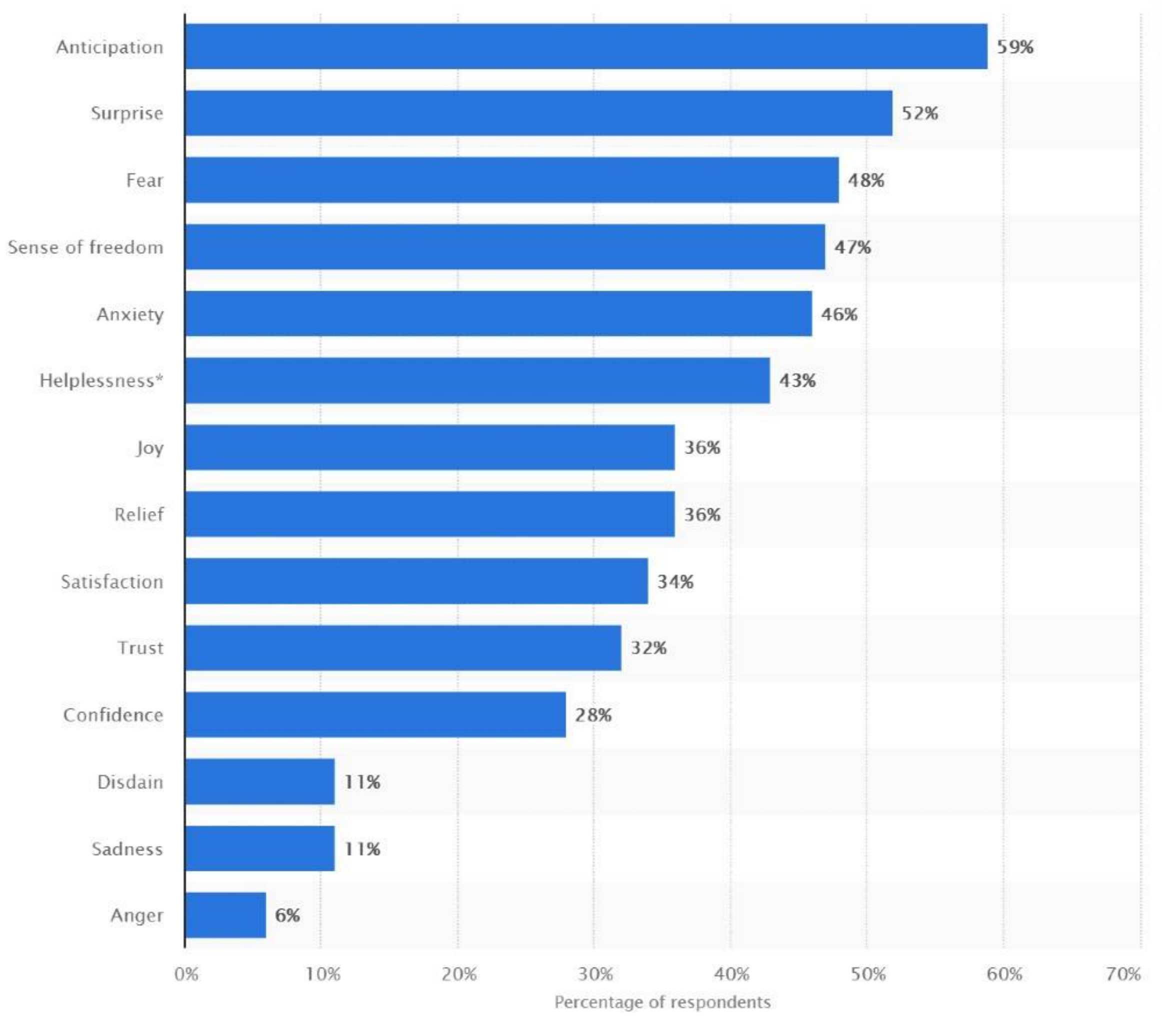


Fig. 4. Emotions caused by autonomous or automated cars as of 2019 [8]



Object detection field test. The test must show that the ALKS is capable of detecting another road user in the forward detection area up to the declared detection range. The required distance is at least 46 meters. Object detection test at the front of the vehicle, requires to use the targets of the motorcycle located on the outer edge of each adjacent lane, a stationary pedestrian target located on the outer edge of each adjacent lane, a stationary motorcycle that is on the lane of the ALKS vehicle and a stationary pedestrian on the track of the vehicle with ALKS.
Detection area range test on the side of the vehicle. This test is intended to demonstrate that the detection range is sufficient to cover the full width of the lane immediately to the left and right of the ALKS vehicle. The sideways object detection test should be performed with the motorcycle target approaching the ALKS vehicle from the left and adjacent right lane.

6. Social benefits and concerns about introducing autonomous and automated vehicles into traffic.

The introduction of autonomous or automated vehicles into traffic may cause a social discussion on the technical solutions of vehicles and road infrastructure. Driving autonomous or automated vehicles will require the removal of technological, regulatory and legal obstacles. The autonomy or automation of vehicles will give rise to many new social, environmental and legal aspects that will have to be considered in the context of social acceptance. Based on statistical surveys conducted in 2019 (Fig. 4), 59% of respondents perceive autonomous or automated vehicles positively as predictable, but at the same time 48% indicate fear of them. It should be emphasized that only 32% of the respondents trust them. In addition automated vehicles create a sense of freedom for 48% of responders and 36% of responders feel relief during driving automated vehicles but the same percentage of respondents also feel helplessness. This means that drivers still need time to trust automatic driving system in vehicles.

Such results indicate a certain distrust of the public towards automatic driving technology. It is obvious that autonomous and automated vehicles will provide new services for the mobility of people, including those with disabilities. The EESC [9] is convinced of the significant benefits for society resulting from equipping vehicles with automated driving systems such as the ALKS.
The introduction of automated and autonomous systems in vehicles will result in fuel savings resulting from the flowing traffic of vehicles, and thanks to fully automated driving, the driver will be the passenger of the vehicle. The development of automation and autonomy in vehicles is the aforementioned increase in accessibility and mobility of people who were previously unable to drive due to physical or mental limitations. The introduction of autonomous vehicles will reduce the total number of cars by increasing the car-sharing. It is estimated that the introduction of autonomous systems will reduce the total number of cars. In the field of urban transport, laminar vehicle traffic will reduce congestion in urban traffic and thus have a positive impact on the environment and air quality. Automatic driving systems will reduce the number of fatalities and serious deaths in road accidents. Due to the fact that the driverless (autonomous) car scrupulously obeys the traffic regulations, it stays in its lane, never forgets to signal a manoeuvre, obeys all signs in particular and does not overtake when cornering. As a result, the improvement of autonomous vehicle technology will have a positive effect in the future in terms of traffic safety.

7. Summary

Automated and autonomous cars require the development of uniform requirements and test conditions as well as type-approval provisions in order to harmonize the safety standards of such vehicles. For this purpose, the European Commission and the United Nations are developing regulations, requirements and test scenarios in order to implement further automation systems in the vehicles. The aim is to ensure the safety of users and to reduce the negative effects of such vehicles traffic on the roads. This requires to develop uniform requirements, test procedures, situations and the response of the automatic system to the existing dangers. Autonomous vehicle response test procedures should be developed in such a way as to include as many road situations as possible in which the vehicle can participate. This implementation model aims to ensure public acceptance and minimize the fear of introducing such vehicles. Lack of trust due to accidents caused by a wrong reaction of the automatic driving system will prevent users from using such automatic systems, and consequently they will not need them.

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