Automatic Braking Systems and Blind Spot as Examples for New Approaches in Type Approval Regulations towards Robust Active Safety Systems

Patrick Seiniger
German Federal Highway Research Institute (BASt)

Paper Number 23-0267

ABSTRACT

Traditional type approval regulations typically define a small set of very precisely defined test cases that act as an implicit requirements definition. Especially for active safety regulations, this leads to two major problems: Firstly, the implicit requirements are given only for a small number of operating points, and secondly, the prescribed test cases will typically happen only on an ideal test track.

The newest type approval regulations, such as especially the new regulation on automated emergency braking systems for heavy vehicles, define requirements in a broader way over the whole operating range, in a certain range of parameters (such as: for centerline offsets between -20 and +20 cm) and leave provisions for technical services and/or market surveillance authorities to test in different, more realistic conditions. They also require the systems to not change strategy for cases out of the specifications (e.g.: for higher centerline offsets).

As a consequence, this shifts the specification responsibility away from the regulator, towards the vehicle manufacturer. In this way, there is more freedom of design while still maintaining an appropriate level of safety. Also, the verification task is shifted towards the technical service, who now has the responsibility to certify that the vehicle or system matches the given overall requirements by specific test cases. The market surveillance authority, however, has the freedom to check each and every aspect of the system against the requirements. Market surveillance therefore acts as a supervisor for the technical services.

In the proposed paper, this new approach is presented in detail with the examples of Regulation 131-02 (automated emergency braking for heavy vehicles) and Regulation 151 (blind spot information systems). The new approach is described in detail with examples from the regulation, as well as the necessary equipment to perform the test runs in the case of Regulation 151: driving robots, robot-controlled bicycle dummy etc. Finally, proposals will be given on how to judge whether a system complies with the requirement to not change strategy; a topic that will become relevant in the coming years.

The combination between broad requirements, not changing system strategy when out of the main operating range, vague defined test cases and market surveillance as a supervisor for technical services has the potential to make the type approval system fit for the future, and especially for all intelligent or flexible or programmable safety systems, on the one hand.

On the other hand, technical services will have to adapt to the new responsibility and manufacturers to the new flexibility, since the regulation now does not exactly specify (overspecify?) a safety system, but more specifies the expected risk balance. It will certainly take some time and discussions until the new approach will fully unfold its potential.

INTRODUCTION

Flexible, programmable or intelligent (FPI) systems are a challenge for the traditional type approval regime: It is hard to define few worst case test cases with which the expected performance of those systems over the whole operating range can be verified, since there is not necessarily a strictly monotone dependency between test parameters and test outcome, like it in general is for classical mechanical systems, see example in Figure 1.

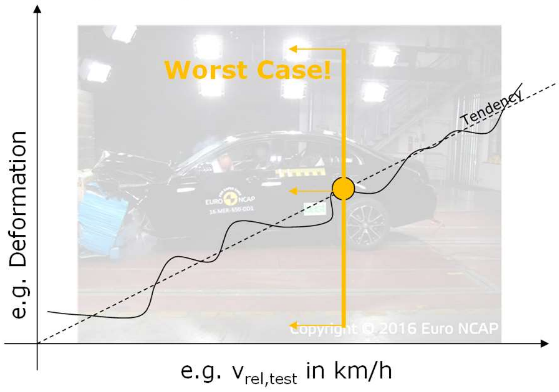

Figure 1: Example for the tendency between test parameter ($v_{rel,test}$) and test result (deformation)

FPI systems in the type approval regime include advanced driver assistance systems, automated driving systems, but also emission-limiting systems, noise pollution prevention and others. This challenge was brought to the attention of the public in 2015 in the course of the emissions scandal where vehicles were designed to function during type approval procedures, but not in real driving conditions – in some cases a good example of test optimization, in other cases a breach of the rules.

A new approach for type approval helps to make the type approval system more robust against test optimization and make it effective also for FPI systems, which we will see in the future in more and more type approval disciplines.

NEW REGULATION APPROACH VS. TRADITIONAL REGULATIONS

The new approach, as opposed to the traditional type approval regulation consists of four elements that help to overcome the weakness that comes with only a limited set of tests. A comparison for key elements of the new approach with traditional regulations is shown in Figure 1.

Table 1: Comparison of new approach and traditional regulations

Category	New approach	Traditional regulations
Requirements definition	Explicit, over the whole operating range, with interpolation tables, functions etc.	Implicit by expected test results, for representative test cases only
Performance off-cycle	Requirement to not change control strategy	-
Test case definition	Vague, As a guidance: other conditions can be tested as well, Expected test results given per reference to requirements	Precise, Test of other conditions not foreseen, Expected test results given with test definition
Number of test cases	Typically high number of test cases, procedure how to deal with failed tests	Typically low number of test cases
Surveillance system	Market surveillance, Conformity of Production	Conformity of Production

The differences with regard to these items will be explained in this section.

Explicit vs. Implicit Requirements

Requirements are implicit if the requirements are not specified in general terms but result from the pass criteria of a limited test program. For this the precise description of the tests and the respective pass criteria is necessary.

With implicit specification, the system or vehicle to be tested can be regarded as a "black box" whose internal decision-making procedures are unknown. Verification by means of tests is therefore possible in principle even without manufacturer knowledge. Moreover, the method is easy to practice (tests are clearly predefined and do not have to be adapted to the specific product, the expected outcomes are clearly described as pass criteria). Typically, environment conditions for the test, such as weather, test surface, vehicle configuration are exactly specified. The disadvantage of this method – important for robust driver assistance systems regulations – is that performance requirements for conditions other than the test conditions are not specified.

Thus, one approach that is becoming increasingly prevalent in more recent driver assistance regulation documents is the concrete, numerical or mathematical definition of verifiable requirements. These requirements - unless further restricted - apply comprehensively (for example: for all driving speeds, for all weather conditions, for all vehicle configurations and so on).

In many cases, the function fulfilment (example: emergency brake assist function) is neither physically nor technically possible in every situation. Comprehensible restrictions are then specified (in the example: definition of speed reduction for dry road surfaces).

"Do Not Change Strategy" – Off-Cycle Performance Requirements

Additionally, robust systems should try to do their best to avoid accidents, even outside of the range for which requirements are defined. Therefore, a typical requirement is that the corresponding function must not exhibit any unjustified switching of the control strategy even outside the restrictions**.**

Vaguely Defined Test Cases for Explicit Requirements

As stated above, traditional type approval regulations specify the tests very precisely. This ensures that the tests done by different technical services are comparable. However, this method does allow optimization for the test. A more important challenge is that for flexible, programmable and intelligent systems, the fact that tests in worst-case conditions are passed does not necessarily mean that test in other, non-worst-case conditions the tests are passed as well. For explicit requirements, it is not of great importance to exactly specify test conditions since the performance requirements are defined independent from test cases. Under some circumstances, it can be an advantage to only define tests very vaguely, allowing technical services and market surveillance authorities to explore the performance of the system over the whole operating range.

However, the effort required to test the requirements can increase considerably when applying this method, and the test cases will not necessarily be the same in number and parameters for each type approval test series. Moreover, in some cases, the tests that remain in the regulations are so vaguely defined that technical services, type approval and market surveillance authorities must have a deep understanding of possible system limits (for example, in the application of UN Regulation No. 157 on automated lane-keeping systems).

Test definition will also allow testing of off-cycle performance ("do not change strategy"); in this case, identifying the expected performance is not trivial. A method for this is proposed below.

Market Surveillance Process

Previously, under the European Framework Directive 2007/46/EC, once a type approval had been granted by one member state of the EU, it could only be questioned and reviewed by another member state with high hurdles, the only quality control process over the lifetime of a product was the so-called "Conformity of Production", where the conformance of the produced products with the type-approved products is checked. The new Framework Regulation (EC) No. 2018/858 introduces the system of so-called market surveillance. It now allows any vehicle type-approved granted on the basis of the Framework Regulation to be inspected by the market surveillance authorities of the member states or the Joint Research Center of the European Commission with regard to compliance with the requirements. It is not yet fully clear how exactly market surveillance will be implemented. However, it has the potential to fundamentally change the type approval system.

Without market surveillance, generically formulated test cases (example: "braking from any speed", as opposed to precisely specified test conditions "braking from X km/h with tolerance Y") could be a disadvantage, because it is then up to only one technical service and one type approval authority to verify compliance with the requirements, and this one technical service could possibly select parameter combinations that are particularly easy to meet without further specifications.

With market surveillance, generically formulated test cases are advantageous because not only the initial technical service and the approval-issuing authority check compliance with the requirements, but potentially many other member states can also do so on the basis of possibly completely different test cases. The vehicle manufacturer is therefore forced to design the system robustly. Optimization for the "one" test is no longer possible without the risk of sanctions.

This requires a rethink in the formulation of vehicle technology regulations towards the specification of generally valid requirements (especially in the case of driver assistance systems), which are not limited - as in the past - to a few requirements specified by concrete test cases. The generally valid requirements can be verified by more and generically defined test cases. Because artificial target objects often used in tests can by their very nature never fully represent reality and can lead to malfunctions, this then also includes the creation of opportunities for retesting (in case of fails) on a limited scale with clear definition of criteria for test repetition.

IMPLEMENATION IN REGULATIONS (UN) NO. 131-02 & 152, AUTOMATIC EMERGENCY BRAKING SYSTEMS

An automatic emergency braking system regulation was amongst the first advanced driver assistance system regulation in the UN ECE framework. After a major overhaul, which resulted in the second series of amendments to Regulation (UN) No. 131 and pending modifications to Regulation (UN) No. 152, AEBS regulations are now amongst the most modern regulations. They showcase how the "new approach" as defined in the last section can be implemented. This will be discussed in the following section; text with grey background in this section is taken from Regulation 131-02 (document GRVA-12-50rev1).

Requirements Section

The "new approach" starts with a formulation of verifiable requirements for the system. Verifiable requirements do not contain items like "long", "small", "short" etc., but contain concrete values.

Regulation (UN) No. 131-02 [1] has the performance requirement for the automatic braking function in paragraph 5.2.1.4 (and some others for other AEB functions).

Performance Statement

The paragraph starts with the statement that the required performance is stated for a set of conditions:

> *5.2.1.4. Speed reduction by braking demand*
> *In absence of driver's input which would lead to interruption according to paragraph 5.3.2., the AEBS shall be able to achieve a relative impact speed that is less or equal to the maximum relative impact speed as shown in the following table, provided:*

A list of conditions follows that defines the boundary conditions for when the performance targets are required to be achieved. They are derived from the scope of the regulation (here: an assistance system that aids the driver, but is not able to avoid each and every accident automatically).

Environmental Conditions

The conditions in the case of R131-02 are grouped into a list of four exhaustive items, starting with the condition that the environmental conditions allow for maximum brake decelerations – which means that adoption of the control strategy to other conditions such as low friction is not required (which is different to regulations for automated driving systems such as R157 [2]). Note that this item, like almost all items, contains an exhaustive list as well.

> *(a) Vehicle external influences allow for the required deceleration, i.e.:*
> *(i) The road is flat, horizontal and dry affording good adhesion;*
> *(ii) The weather conditions do not affect the dynamic performance of the vehicle (e.g. no storm, not below 0°C);*

Note that this looks like ideal conditions on the test track in the first place, but it requires the full performance also close to metal guardrails, sign posts, with lane markings and the like – since all these items are not excluded. This is a major step towards robustness of the regulation.

Vehicle Conditions

The next group defines that the vehicle itself shall be able to achieve the required deceleration, giving examples, not an exhaustive list. The reasoning behind this is that the vehicle's possible deceleration can be impaired by improper maintenance and other facts not under the control of the vehicle manufacturer. An item to keep in mind for later discussions is the trailer under bullet (iv), which is typical for the operation of heavy vehicles.

> *(b) The vehicle state itself allows for the required deceleration, e.g.:*
> *(i) The tyres are in an appropriate state and properly inflated;*
> *(ii) The brakes are properly operational (brake temperature, pads condition etc.);*
> *(iii) There is no severe uneven load distribution;*
> *(iv) No trailer is coupled to the motor vehicle and the mass of the motor vehicle is between maximum mass and mass in running order conditions;*

Perception Conditions

While the upper two condition groups look at whether full deceleration is possible, AEBS systems also require the targets to be detectable. Some environment conditions, mainly water in the air, decrease the possible RADAR sensor performance, and bad visual conditions are a problem for camera sensors. This lead to the definition of the following conditions, again an exhaustive list:

> *(c) There are no external influences affecting the physical sensing capabilities, i.e.:*

(i) The ambient illumination conditions are at least 1000 Lux and there is no extreme blinding of the sensors (e.g. direct blinding sunlight, highly RADAR-reflective environment);
(ii) The target vehicle is not extreme with regard to the Radar Cross Section (RCS) or the shape/silhouette (e.g. below fifth percentile of RCS of all M1 vehicles)
(iii) There are no significant weather conditions affecting the sensing capabilities of the vehicle (e.g. no heavy rain, dense fog, snow, dirt);
(iv) There are no overhead obstructions close to the vehicle;

Situation Conditions
The condition set (again an exhaustive list) that limits the performance of the AEBS probably the most looks at the situation itself. Regardless of the sensor capabilities and the deceleration capabilities, the internal logic of the system needs to be able to make appropriate decisions. Most of the items in this list are there to prevent false-positive braking interventions due to a misunderstanding of the system.
It is expected that increasing experience with systems and the progress of the state of technology might allow to reduce there conditions in the future.

(d) The situation is unambiguous, i.e.:
(i) The preceding vehicle belongs to Category M, N, O3 or O4, is unobstructed, clearly separated from other objects in the driving lane and constantly travelling or stationary;
(ii) The vehicle longitudinal centre planes are displaced by not more than 0.2 m;
(iii) The direction of travel is straight with no curve, and the vehicle is not turning at an intersection and following its lane.

Off-Cycle Performance Statement
The performance requirements paragraph ends with a very important statement, requesting that there shall be no deactivation or switch in the control strategy when the conditions in the condition list are not all met (=one or more of the conditions are not fulfilled).

When conditions deviate from those listed above, the system shall not deactivate or unreasonably switch the control strategy. This shall be demonstrated in accordance with paragraph 6 and Annex 3 of this Regulation.

This statement is a key point to achieve robust AEBS performance, yet it is still unclear how this criterion will be verified during type approval or market surveillance processes, especially for the "change of strategy", while deactivation can be easily verified. A proposal for some conditions will me made below.

Numeric Performance Requirements
Finally, the paragraph closes with a lookup table and interpolation guidance, giving the maximum allowed impact speed as function of the initial relative speed, an excerpt is shown in Table 2. This table defines the required performance for all operating points within the condition set as explained above.

Table 2: Maximum relative Impact Speed (km/h) (regardless whether target stationary or moving)*

Relative Speed (km/h)	*M3>8t, N2>8t, N3*
10	0
20	0
30	0
35	0
40	0
50	0
60	0
70	0
80	28
90	42
100	54***

Tests

The test section according to the new approach does no longer define the required performance, as it was the case with implicit requirement definition. On the other hand, the parameter range for expected performance is much larger than for traditional regulations, which makes it virtually impossible to test the system against all parameter combinations.
The test section therefore has two purposes: Its main purpose is to define a minimum set of system tests to ensure a basic safety level in standardized conditions, quite similar to traditional regulations.
Its other purpose is to open up a path for testing different conditions like speeds, surroundings, etc., to verify the full parameter range as specified in the performance requirements, and allow for testing of changing the control strategy.
The core of the test section is paragraph 6.5, which starts with the traditional test description:

6.5. Warning and Activation Test with a Moving Vehicle Target
The subject vehicle and the moving target shall travel in a straight line, in the same

direction, for at least two seconds prior to the functional part of the test. with a subject vehicle to target centreline offset of not more than 0.2m. Tests shall be conducted with a vehicle travelling at the following relative speeds to the target, with a tolerance of +/- 2 km/h for all tests, and a target travelling at 20 km/h, with a tolerance of +0/-2 km/h for both the target and the subject vehicles, but at speeds not beyond the range specified in paragraph 5.2.1.3.:
(a) 20 km/h (e.g. target travelling at 20 km/h, vehicle travelling at 40 km/h, relative speed is 20 km/h);
(b) Maximum required impact avoidance speed as shown in paragraph 5.2.1.4 (e.g. maximum required impact avoidance speed for a N3 vehicle is 70 km/h, target is travelling at 20 k/h, vehicle speed is 90 km/h), and
(c) Either:
(i) Maximum required impact avoidance speed, as shown in paragraph 5.2.1.4., + 8 km/h (e.g. for a target travelling at 20 km/h and a M3 vehicle > 8 tons, the test shall be conducted at 20 + 70 + 8 = 98 km/h), or
(ii) Maximum design speed (e.g: for a target travelling at 20 km/h, speed limiter speed of approximately 89 km/h for an N3),
whichever is lower.

The following paragraph allows to test other conditions. This allows the technical service to perform additional verifications when in doubt, and on the other hand to allow market surveillance authorities to verify every aspect of the performance requirements when re-testing a vehicle.

If this is deemed justified, the technical service may test in any test condition within the conditions specified in paragraph 5.2.1.4. and with any other speeds listed in the tables in paragraph 5.2.1.4. and within the prescribed speed range as defined in paragraph 5.2.1.3. Outside of the conditions of Paragraph 5.2.1.4., the Technical Service may verify that the control strategy is not unreasonably changed or AEBS switched off. The report of this verification shall be appended to the test report.

This implementation of the test definitions serves the purpose to have technical services test at least a minimum set of tests, and on the other hand allow technical service and market surveillance to assess the full performance requirements – thus forcing vehicle manufacturers to develop robust systems working under all conditions, especially in real traffic.

VERIFYING OFF-CYCLE PERFORMANCE FOR AEBS REGULATIONS

While performance requirements over a range of various parameters are clearly defined, and also the deactivation as absence of performance can be identified quite easily, the remaining challenge is how to verify whether a specific system does not unreasonably switch the control strategy when out of these conditions.

Possible Deceleration Lower Than Reference Case

The aim of this section is to propose criteria for this case, based on the safety models applied during the definition of the recent AEBS regulations.
The required speed reduction has been derived from a simple model with the following parameters:

- the maximum possible deceleration for a given surface, given by the friction coefficient μ,
- the time required to reach the maximum deceleration, t_{buildup},
- the TTC value for the start of brake intervention, TTC_{Brake}.

With these parameters, the possible avoidance speed would be approximately
$v_{avoidance} = 2 \cdot \mu \cdot g \cdot (TTC_{Brake} - 0.5 \cdot t_{buildup})$,
or for situations where the friction is not the issue, but the deceleration is limited to d_{lim}:
$v_{avoidance} = 2 \cdot d_{lim} \cdot (TTC_{Brake} - 0.5 \cdot t_{buildup})$.
For instance, two items from the performance section of Regulation 131-02 look at whether the required deceleration is possible:

(a) Vehicle external influences allow for the required deceleration, i.e.:
(b) The vehicle state itself allows for the required deceleration, e.g.:

An unreasonable switch of the control strategy could in this case be a different, later brake intervention TTC_{Brake}. The maximum avoidance speed in reference conditions and the expected avoidance speed in lower deceleration conditions should relate to each other according to
$$\frac{v_{avoidance,reference}}{v_{avoidance,lower\ deceleration}} = \frac{\mu \cdot g}{d_{lim}},$$
if the control strategy (=brake intervention timing) is the same.

Sensor Influences

In conditions under the third item, the target is detected later or not at all, this requires individual experiments to understand whether a control strategy is unreasonably switched or not:

(c) There are no external influences affecting the physical sensing capabilities, i.e.:

Ambiguous Situation

The last remaining item, limiting the required performance to unambiguous situations, is probably the most complex to deal with switching the control strategy:

(d) The situation is unambiguous, i.e.:

For its first sub-item, the decelerating target is missing; however, this is simple due to the fact that a numerical speed reduction as function if the relative speed is meaningless when the relative speed changes over time.

One method to identify whether the control strategy is changed could be to compare the TTC for the beginning of the brake intervention with the so-called 'enhanced TTC', a variable taking the changing velocities into account [3]:

(i) The preceding vehicle belongs to Category M, N, O3 or O4, is unobstructed, clearly separated from other objects in the driving lane and constantly travelling or stationary;

The lateral displacement, or – more important – the overlap between two vehicles determines the last time to steer: the less overlap exists, the more likely is a successful avoidance maneuver quite late before the collision. Identifying whether a control strategy has changed could be done by comparing the TTC for the last time to steer around in reference conditions (+/- 0. 2 m as stated below) to the TTC for the last time to steer in the situation under question.

The reference lateral acceleration could be calculated with the assumption

$$\Delta y = a_y t^2,$$

the generic equation for displacement (known from the overlap in the reference case) as function of lateral acceleration a_y (to be calculated and rechecked for the non-reference situation) and time t.

(ii) The vehicle longitudinal centre planes are displaced by not more than 0.2 m;

For the final sub-item, it is hard to identify a general mathematical method for change of strategy. A proposal could be to identify the horizontal aperture of the sensor system (RADAR and camera) and checking whether the target was within the aperture at all times.

(iii) The direction of travel is straight with no curve, and the vehicle is not turning at an intersection and following its lane.

To sum up, there are several methods for identifying whether the control strategy has changed. Whether or not this switch or deactivation is unreasonable will probably require a justification from the vehicle manufacturer.

IMPLEMENTATION IN REGULATION 151, BLIND SPOT INFORMATION SYSTEMS

Requirements

Regulation 151 in its original form follows partly the traditional regulation, since it has several pre-defined test cases with implicit specification of the requirements. To still have benefits from the "new approach", there are several measures in place. The core text of Regulation 151 does give vague requirements and allows the testing of other conditions than those specified in the (implicit) test case table [4]:

5.3.1.4. The BSIS shall give an information signal at last point of information, for a bicycle moving with a speed between 5 km/h and 20 km/h, at a lateral separation between bicycle and vehicle of between 0.9 and 4.25 metres, which could result in a collision between bicycle and vehicle with an impact position 0 to 6 m with respect to the vehicle front right corner, if typical steering motion would be applied by the vehicle driver.

The information signal shall not be visible before the first point of information. It shall be given between the first point of information and the last point of information. The first point of information may be calculated for any impact position by increasing with the difference between 6 m and impact position.

It shall also give an information signal if a bicycle is detected at a lateral separation of between 0.25 up to 0.9 m longitudinally at least located at the most forward front wheel while driving straight.

However, the specifications how this can be achieved are given in the test section, which is not in line with the "new" approach, since this is a further specification of the requirements shown above:

6.5. Blind Spot Information Dynamic Test
6.5.1. Using cones and the bicycle dummy, form a corridor according to Figure 1 in Appendix 1 to this Regulation and the

additional dimensions as specified in Table 1 of Appendix 1 to this Regulation.
[…]
6.5.10. The test is passed when the Blind Spot Information signal has been activated in all test cases as shown in Table 1 of Appendix 1 to this Regulation before the vehicle has crossed line C (see paragraph 6.5.7. above) and the Blind Spot Information signal has not been activated in any test run when the vehicle passes the traffic sign (see paragraph 6.5.8. above).
For vehicle speeds up to 5 km/h, it is deemed satisfactory if the information signal is activated 1.4 seconds before the bicycle has reached the theoretical collision point as specified in Appendix 1, Figure 1. For vehicle speeds between 5 and 10 km/h, the value dc shall be 5 m.
For vehicle speeds above 25 km/h, where the stopping distance is higher than 15 m, dc as specified in Appendix 1, Figure 1 shall be as specified in Appendix 1, Table 2.

However, the vague definition of requirements allows an alternative specification for test cases that is more in line with the “new approach”. The so-called “alternative testing annex” has been adopted by WP.29 and will enter into force in May 2023.

- It follows the following principles:
- Generic methods for heavy vehicles turning are given by so-called envelopes through which typical drivers shall navigate the vehicle.
- The trajectory of the vehicle is recorded and then exactly replayed by robot control.
- In the replay, a robot-controlled bicycle dummy is added so that a collision will occur.
- Finally, the information signal timing is checked for sufficient stopping time (i.e. was it possible with a deceleration of 5 m/s² and a reaction time of 1.4 seconds after the blind stop information signal was given to avoid the accident?).

This new approach here forces manufacturers to specify their system for traffic safety and makes a fine-tuning towards few test cases impossible.

TEST EQUIPMENT

The new approach requires equipment beyond what is currently used in type-approval testing:

- a precise position measurement system for the vehicle in order to identify whether the vehicle was within the operating range,
- driving robots to make the ego vehicle as well as the target systems follow precisely programmed trajectories,
- several exactly controllable target systems that allow to approach the borders of the operating range as close as possible.

Position measurement systems

State of the art in position measurement nowadays are sensor fusion systems with differential GNSS and inertial measurement units. These devices achieve an accuracy up to +/- 1 cm, with typical values below +/- 10 cm. An example for such a system, fitted to a test vehicle, is shown in Figure 2 below.

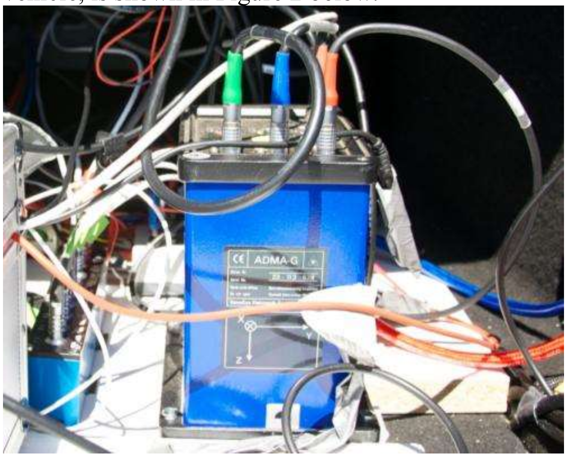

Figure 2: DGPS and inertial measurement system

Driving Robot Systems

Based on precise position measurement, driving robots control any given vehicle by modulating their driving controls (steering wheel, accelerator and brake pedals). The achieved accuracy varies with dynamics, vehicle and how well the robot systems are tuned towards the concrete vehicle and lie in the order of magnitude of 10-50 cm even in complex turning situations. See Figure 3 below for an example of a vehicle.

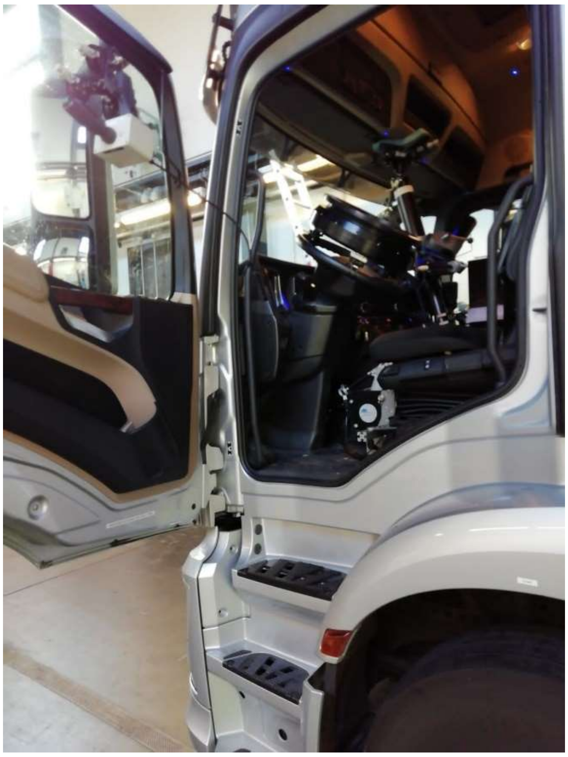

Figure 3: Steering and pedal actuators, mounted in a N_3 tractor vehicle

Robotic Target Systems and Targets

Robotic target carriers are flat over-runnable platforms where a variety of surrogate targets resembling passenger cars, pedestrians, bicycles or motorcycles can be fitted, see Figure 4 to Figure 7. The platforms include a precise position measurement system and control logics comparable to the driving robot systems, allowing them to achieve approximately the same precision in control.

Figure 4: Car dummy on robotic target carrier

Figure 5: Bicycle dummy on robotic target carrier

Figure 6: Motorcycle dummy on robotic target carrier

Figure 7: Pedestrian dummy on robotic target carrier

CONCLUSIONS

A new approach for the formulation of vehicle technical regulations has been presented that is specifically helpful for advanced driver assistance system and automated driving system regulations, but for some others as well.

The aim of this new approach is to make design of systems simply towards test criteria impossible and to force manufacturers to develop robust systems that will deliver the required performance in realistic surroundings.
This is achieved by three measures: First, by precise formulation of verifiable performance requirements over the whole relevant operating range, and asking for no unreasonable change of the system strategy outside of this operating rage. Second, by allowing tests in all operating points to be performed, so that it is unclear in the beginning as to what exactly could be tested, besides a set of standard tests (that still are defined in the regulations and will always be tested). Third, not part of the regulation itself, by a market surveillance system that allows retest of randomly selected or suspicious vehicles by independent authorities against the regulations.
The implementation of these three measures in new regulations as well as appropriate measurement equipment has been shown in the paper.
The new approach however brings also a shift of responsibility for defining test cases from the regulator towards the technical services and towards the market surveillance authorities, requires more test cases to be conducted and more considerations on what is a relevant and valuable test to assess the vehicle or system characteristics.

REFERENCES

[1] United Nations Economic Commission for Europe: Regulation (UN) No. 131-02. Available as document GRVA-14-50-rev1 for download at https://unece.org/sites/default/files/2022-01/GRVA-12-50r1e.pdf.

[2] United Nations Economic Commission for Europe: Regulation (UN) No. 157. Available for download at https://unece.org/sites/default/files/2021-03/R157e.pdf.

[3] Winner, Hermann: “Grundlagen von Frontkollisionsschutzsystemen“. In: Winner et all (Editors): “Handbuch Fahrerassistenzsysteme”. P. 893-912. 3. Edition, Springer Verlag, Wiesbaden, 2015.

[4] United Nations Economic Commission for Europe: Regulation (UN) No. 151. Available for download at https://unece.org/sites/default/files/2021-08/R151e.pdf.