



Approval Verification Testing

JRC Proposals on track and public-roads testing

Verification testing principles

1. Fair and transparent testing for all
2. Complementarity between testing on track (controlled environment) and on public-roads (real world)



Verification through track testing

Proposal to amend UNR 157 – Annex 5

UN Regulation 157 on ALKS now

- **Purpose:** Limited to the verification of technical requirements
- **Test conditions:** *"The tests shall be performed under conditions (e.g. environmental, road geometry) that allow the activation of the ALKS."*
i.e. within the ODD
- **Test parameters variation:** *"The manufacturer shall declare the system boundaries to the Technical Service. The Technical Service shall define different combinations of test parameters (e.g. present speed of the ALKS vehicle, type and offset of target, curvature of lane) in order to cover scenarios in which a collision shall be avoided by the system as well as those in which a collision is not expected to be avoided, where applicable.
If this is deemed justified, the Technical Service may test additionally any other combination of parameters."*

Test Scenarios to assess the DDT in the current regulation (Annex 5)

- Lane keeping
- Avoid a collision with a road user or object blocking the lane
- Following a lead vehicle
- Lane change of another vehicle into lane
- Stationary obstacle after lane change of the lead vehicle
- Field of View test

Additional verifications in the current regulation (Annex 5)

- Off mode after new engine start/run
- System can only be activated if
 - (a) The driver is in driver seat & belt is fastened
 - (b) The driver is available
 - (c) No failures
 - (d) DSSAD operational
 - (e) Conditions are within system limits
- Means of deactivating
- Dedicated means to activate and deactivate
- Protected against unintentional action
- Steering...
- System override possibilities
- Criteria for deeming driver available
- Driver attentiveness
- ...

Discussions triggering the review

1. Speed increase: 60->130 km/h

- Ensure realistic testing speeds over the full speed range

2. Lane change possibility

- Make lane change capability mandatory for high speed?



Comfort lane change <-> evasive maneuver

- Additional testing needed (scenarios)

Identified issues

1. Track testing and public road testing mixed in one Annex with different importance levels:

EC proposal: two separate Annexes with same level and elaboration.

2. The aim of track testing:

- Evaluation of critical scenarios (complementarity with onroad testing, derived from NATM main document):

“The authority shall verify the system in a fault-free condition on a closed-access testing ground with various scenario elements to test the capabilities and functioning of an ADS in critical and emergency conditions.”

Identified issues

3. Scenarios for track testing:

EC proposal: a new set of scenarios only for track testing:

- Avoid a collision with a road user or object blocking the lane
- Following a lead vehicle
- Lane change of another vehicle into lane
- Stationary obstacle after lane change of the lead vehicle
- Avoid braking before a passable object in the lane
- String stability
- Oncoming traffic / Wrong way driver
- Transition demand

Identified issues

4. Definitions of test conditions: identify avoidable vs non-avoidable collision

EC suggestion: use Fuzzy performance model to identify non-avoidable scenarios.

5. Definition of test conditions: discard non-realistic test conditions within the ODD

E.g., testing at very low speeds in free flow conditions in critical traffic scenarios.

Identified issues

6. Definition of test conditions: ensure a fair and standardized mix of situations with (1) trivial/easy (2) medium (3) difficult or (4) non-avoidable collision scenarios

“The composition of a series of tests in a certain critical scenario shall be as follows:

- **[30] % of all tests shall be in the “medium” parameter range;**
- **[60] % of all tests shall be in the “difficult” parameter range;**
- **[10] % of all test shall be in the “unavoidable collision” parameter range for the given scenario;**

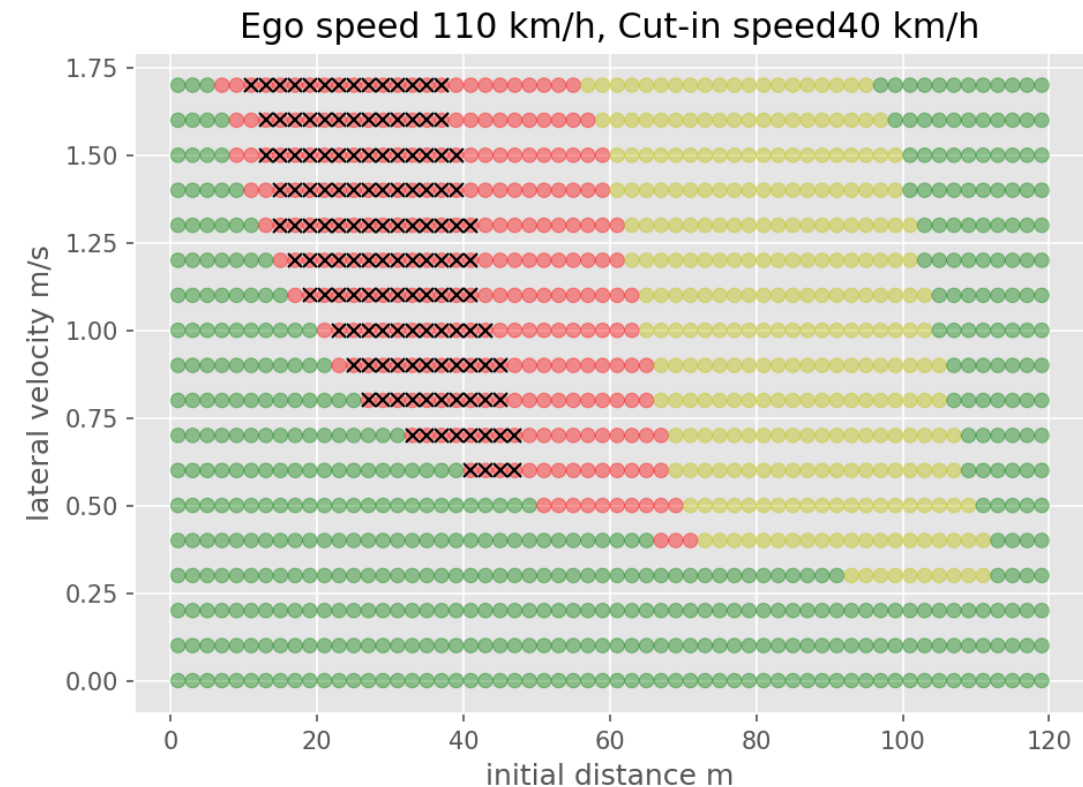
With an accuracy of $[\pm 5]$ % for each range.”

Identified issues

7. Suggested classification of critical traffic scenarios:

“Classification of difficulty of the scenarios based on the initial parameters is done the following way:

- Easy: $PFS \leq 0.85$;
- Medium: $PFS > 0.85$ and $CFS < 0.9$;
- Difficult: $CFS \Rightarrow 0.9$.”



Collision test possibilities - targets

- Most of the target manufacturers offer robot platforms up to 100 km/h (some even up to 120 km/h).
- They are used for at least 80 km/h speed difference between target and VUT (up to 140 km/h in case of oncoming vehicle test).
- Up to these speeds there is no threat of VUT damage during crash tests.



Collision test possibilities in practice

- This means that:
 - During max speed tests (if 130 km/h is the max speed of the VUT) the **Δv is reduced to 30 km/h** (and most collision scenarios are in the higher Δv range);
 - And **Δv can be increased up to at least 80 km/h** without VUT damage.
- As a consequence:
 - **Up to ~90 km/h** ego speed **every scenario is possible** to be considered;
 - Above 90 km/h a range of **[0-30 .. 80] km/h Δv** can be considered as a **minimal value!**

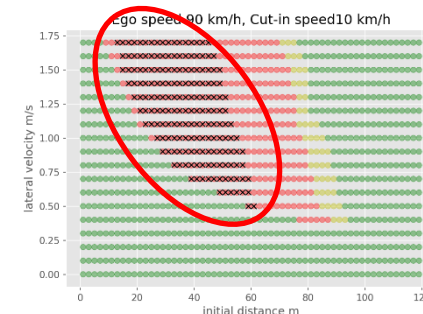
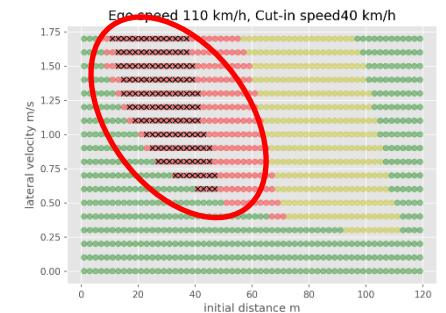
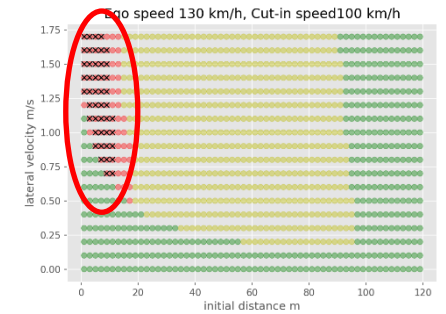
Collision test possibilities in practice

- Examples:

- Ego speed: 130 km/h Possible target speed: 100 – 50 km/h

- Ego speed: 110 km/h Possible target speed: 100 – 20 km/h

- Ego speed: 90 km/h Possible target speed: no restrictions



Identified issues

8. Collision & mitigation strategies

- Current text in R157: *„If a collision cannot be avoided for some test parameters, the manufacturer shall demonstrate either by documentation or, if possible, by verification/testing that **the system doesn't unreasonably switch its control strategy.**”*



- What does “switching control strategy” mean?
- Changing strategy compared to what?

Current definition:

"Control strategy" means a strategy to ensure robust and safe operation of the function(s) of "The System" in response to a specific set of ambient and/or operating conditions (such as road surface condition, traffic intensity and other road users, adverse weather conditions, etc.). This may include the automatic deactivation of a function or temporary performance restrictions (e.g. a reduction in the maximum operating speed, etc.).

Identified issues

8. Collision & mitigation strategies

- Clarification for non-avoidable scenarios:

EC proposal:

“If a collision cannot be avoided, the approval authority shall verify that the system doesn’t significantly switch its control strategy, unless the manufacturer can prove that by doing so the damage caused by the collision to both the ADS and the other road users can be reduced.”

“Control strategy” in this meaning: *strategy of the ADS during critical scenarios to reduce the severity of a possible accident. One strategy can be to use full deceleration of the ADS, another to plan and execute a mitigation manoeuvre (if possible), or a mix of both.*

Identified issues

8. Collision & mitigation strategies

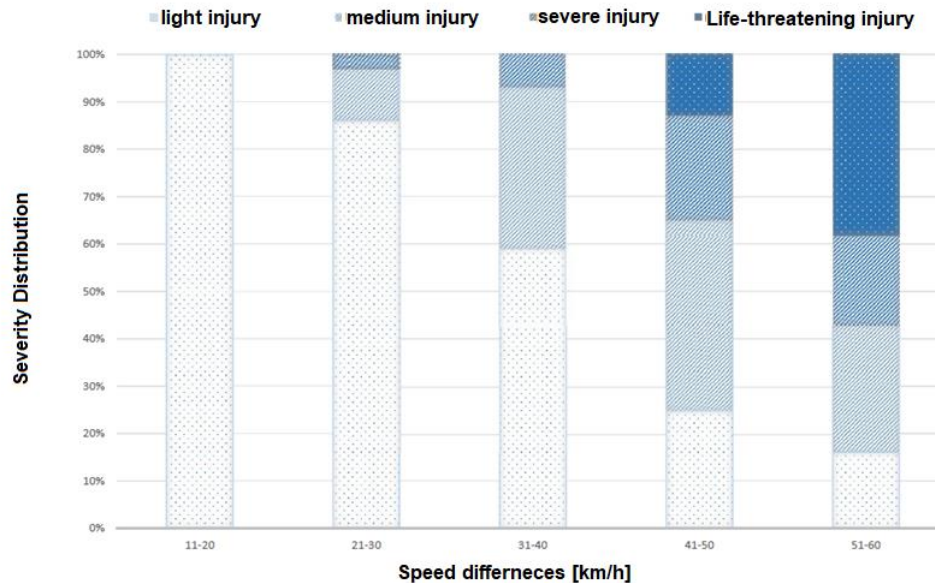
- Collision avoidance is crucial, but
- What does an AV do if the collision is non-avoidable? Mitigation is also very important -> assessment should be worked out

A possible solution: Bring accident expert's knowledge and methods to type approval:

- **With the use of simulation tools recreate the accident virtually, and**
- **Compare it with the results of a nominal case of the same situation.**

Assessment of non-avoidable collisions: getting crucial with the increase of speed

- Correlation between speed difference and accident severity:



With the increase of speed, the significance of collision assessment is increasing!

$$\Delta V = V_{\text{post impact}} - V_{\text{pre impact}}$$

To be able to compare accidents we need to find the proper accident metrics:

- EES** (Energy Equivalent Speed)
- Speed difference before and after the crash of the involved vehicles**

Used by forensic and accident reconstruction experts to describe accident severity

Summary

Highlights of the EC proposal on track testing:

- **Annex 5 reserved** only for testing on closed-access **testing grounds**,
- Clarification of the **aim of track-testing**.
- Including **only scenarios relevant for track testing**, with **new scenarios** in-line with scenario list accepted in VMAD.
- Determination of **non-avoidable scenarios**, **classification of the remaining scenarios** in order **to ensure a fair test composition** according to the aim of track-testing.
- **Assessment** of ADS behaviour **in non-avoidable collision scenarios**.



Verification through public road testing

Proposal to amend UNR 157 – Annex 6

Regulatory Background

- Real-world test of ADS is already reflected in UNECE Reg. 157, Annex 5 Pgh. 5.4
- Today requirements for public road tests are insufficiently defined to have common minimum requirements
- Verification should be robust and efficient
 - Due to the variety and complexity of systems and the complexity of the tests, the verification should be flexible

General principles

The public road test shall primarily verify the ADS normal operation within (but including coming close to) the system boundaries.

- Test Conditions
- Test Scenarios
- Test Duration
- Data collection and Data evaluation

Test Conditions

- Conditions that allow the activation of the ADS and approach the limits of its declared ODD
- The composition of the test shall allow the verification of the system on motorway free-flow condition and/or on motorway dense traffic conditions
- Cover different time-of-day, weather situations and light intensity
- Include situations in which the ADS is expected to experience challenging scenarios (especially tight curvatures, speed changes caused by variable traffic conditions, merging situations)

Test Scenarios

Test scenarios shall be selected depending on the intended operating range

- Lane Keeping
- Following a lead vehicle
- Lane change of another vehicle into lane
- Lane changing
- Response to traffic rules and road furniture
- Prevention of activation when the ADS system is outside the declared ODD
- System override by the driver

Test Duration – Identified concerns

- Systems with substantially different capabilities will be covered by this Regulation
- The prescription needs to be flexible to allow testing of the systems
- Public road testing needs to include a minimum coverage of relevant scenarios that are representative of the system operation
 - This has an impact on the potential test duration

Test Duration

The test, or combination of tests, shall be such that allows recording the ADS operation including:

- at least [5] hours of dense traffic conditions
- And, if applicable, at least [10] hours of free-flow traffic condition, including congested traffic conditions

“Dense traffic conditions” means that ADS operations have the main objective to maintain a safe distance from the surrounding vehicles. In this case the average speed shall be greater than or equal to 15 km/h and lower than or equal to [55] km/h.

“Free flow traffic conditions” means that ADS operations are not heavily affected on a continuous basis by the behaviour of the surrounding vehicles. In this case the average speed shall be greater than to [90] km/h and lower than or equal to either the system maximum speed or the road maximum allowed, whichever lowest.

“Congested traffic conditions” means that ADS operations are affected on a continuous basis by the behaviour of the surrounding vehicles. In this case the vehicle average speed shall be greater than [55] km/h to and lower than or equal to [90] km/h.

Test Duration

- The tests shall include situations where the ADS:
 - a) is involved in merging situations in congested traffic where the number of highway lanes is reduced (at least [10] situations starting from an ending lane and [10] situations from a continuous lane)
 - b) is approaching a standing end of a traffic jam (at least [10] situations);
 - c) is exposed to variable road signs (showing at least 3 different signs).

Data collection – Minimum data channels

- (a) ADS Vehicle longitudinal acceleration;
- (b) ADS Vehicle lateral acceleration;
- (c) ADS Vehicle longitudinal velocity;
- (d) ADS Vehicle lateral velocity;
- (e) ADS Vehicle position;
- (f) ADS Vehicle distance to leading vehicle;
- (g) Leading vehicle relative speed;
- (h) Relative position of the ADS vehicle from lane markings;
- (i) Traffic signs recognition along with their geo-localization;
- ...

Data from the test, or combination of tests:

- shall be recorded and the test vehicle instrumented with non-perturbing equipment;
- not be modified or be removed from the assessed test.

Data evaluation

- The data recorded from activated system shall be assessed for the sections falling within the declared ODD including those sections when the system has left the ODD inadvertently without correctly ending its operation.
- Qualified assessor (or in case use new tools appear for automatic evaluation, they can be used as well) evaluates the ADS:
 - a) Respects the traffic rules;
 - b) Adapts its operations to environmental conditions;
 - c) Does not show an unpredictable behaviour creating a danger to surrounding traffic;
 - d) Shows reasonable cooperative behaviour in relevant situations (i.e. merging in dense traffic).
- Time gap to leading vehicle, time gap left to the upcoming vehicle in the target lane in case of lane-change and lateral position deviation shall be quantitatively evaluated according to the technical requirements in paragraph 5 in this Regulation.

Data exchange and test report

- To be able to replicate the public road test a data exchange file using a commonly agreed format may be needed
- A test report shall be prepared in accordance with a Data Reporting File and shall be made available to the Contracting Parties.

Thank you



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