

Proposal for the Supplement 04 to 02 series of amendments to UN Regulation No. 152 (Advanced Emergency Braking System for M₁ and N₁ vehicles)

Submitted by the expert from France, leading this workstream

The text reproduced below was prepared by the expert from France, with the aim to introduce provisions for using virtual testing as an alternative to physical tests in UN Regulation No. 152. It is based on working document ECE/TRANS/WP.29/GRVA/2024/19. The modifications to the existing text of the Regulation are marked in blue bold for new or strikethrough for deleted characters.

I. Proposal

Add a new paragraph 2.18., amend to read:

~~“2.18. ——— “Virtual testing” is the process of testing a system using one or more simulation models.~~

Add a new paragraph 6.117., amend to read:

~~“6.711.~~ Virtual testing of dynamic tests

~~6.-711.1.~~ Virtual testing may be used by request of the vehicle manufacturer as an alternative for **some of** the tests described in paragraphs 6.4. to 6.6. The ~~provided~~ virtual testing shall be verified and validated according to **Annex 4** and ~~are~~ used in accordance with **Annex 4**.

~~6.-711.2.~~ Virtual testing may be used in the evaluation of the warning and activation tests in accordance with paragraph 1.8. of Schedule 3 and Schedule 8 of Revision 3 of the 1958 Agreement.

~~6.-711.3.~~ ~~In addition to the test runs shall be conducted as physical tests as well on the request of the Type Approval Authority and technical service.~~

In order to demonstrate that the complete physical system can reliably deliver the required performance, at least 30% of required tests shall be performed physically. The tests to be performed shall be agreed between the manufacturer and Type Approval Authority or its technical service.

~~6.-711.3.1~~ Notwithstanding paragraph 6.7.3, in the case of modification of the vehicle type and extension of the approval according to paragraph 7, the proportion of physical tests required to demonstrate that the complete physical system continues to reliably deliver the required performance shall be agreed between the manufacturer and Type Approval Authority or technical.

~~6.-711.4.~~ ~~In case of~~ Where virtual testing is **chosen** used by the manufacturer, a ~~separated~~ report including at least the additional **data** information specified in **Annex 4** ~~paragraph 1.5.~~ shall be annexed to the test report.”

Add a new Annex 4, to read:

“Annex 4

Virtual testing of dynamic tests

0. Introduction (for information only)

This annex describes the method that can be used to consider virtual testing as an alternative to physical testing, based on the manufacturer request.

This method is mainly based on 2 separate activities pillars:

(a) **Activity Pillar 1:** The development, management, verification and validation of the toolchain; ~~virtual testing method by comparison with physical results~~ and,

(b) **Activity Pillar 2:** The use of virtual testing results to conduct testing required for approval process.

1. Definitions

1.1. “Virtual testing” is the process of testing a system using one or more simulation models.

1.2. “Model” is a description or representation of a system, entity, phenomenon or process.

1.3. “Toolchain” is the combination of simulation model implementations as tools that emulate a vehicle function.”

1.4. “Validity domain” is the domain of applicability of the toolchain.

~~12.~~ ~~Validation of the virtual testing method~~ Activity 1: The development, management, verification and validation of the toolchain (~~pillar 1~~)

~~12.1.~~ General specifications

~~1.1.1.~~ ~~The manufacturer shall provide documentation to prove the credibility of the virtual testing results.~~

~~1.1.2.~~ ~~The vehicle manufacturer shall define the validity domain on which the virtual testing will be applicable. This annex only applies within this validity domain.~~

~~12.1.31.~~ Credibility of the virtual toolchain that is used for the virtual testing shall be demonstrated by the vehicle manufacturer to the satisfaction of the Type Approval Authority ~~and or its~~ Technical Service.

For this, the following five criteria shall be considered:

(a) Capability – what ~~virtual~~ the toolchain can do, and what ~~are~~ the associated risks ~~are~~;

(b) Accuracy – how well ~~virtual~~ the toolchain ~~does~~ reproduces the target data;

(c) Correctness – how sound & robust ~~are~~ the ~~used data and~~ the algorithms in the tools;

(d) Fit for Purpose – how suitable ~~is~~ the ~~virtual~~ toolchain ~~is~~ for the assessment (e.g. vehicle dynamic model, sensor model, system control model, environment model, scenario model, targets model, ...) within its validity domain.

(e) Usability – ~~What~~ The training and experience ~~which~~ is needed and ~~what~~ ~~is~~ the quality of the processes that manage its use.

~~1.2.~~ ~~Physical validation tests~~

- ~~1.2.1. At the request of the technical service, in addition to the documentation provided by the vehicle manufacturer, physical tests shall be performed or witnessed to confirm the accuracy between the physical and the simulation results.~~
- ~~1.2.1.1. The number of physical tests to be tested shall be defined in agreement between the manufacturer and the technical service in order to sufficiently cover the validity domain specified by the vehicle manufacturer.~~
- ~~1.2.2. The number of tests performed shall ensure a statistical comparison between physical and simulation results.~~
- ~~4.2.32. Simulation model-Development of the virtual testing method~~
- ~~4.2.32.1. Developing and using the toolchain simulations (including development of the model) shall be run under is the responsibility of the vehicle manufacturer. It The toolchain shall reflect the architecture of the vehicle, system and components that are to be tested. in relation to the requirements of the current regulation and the manufacturer will define its on the specified validity domain.~~
- 2.3. Toolchain management
- The following information shall be provided by the manufacturer to the technical service:
- 2.3.1. A description of the models and tools which constitute the toolchain and the method used to trace input data, parameters and output data back to the corresponding toolchain version.
- 2.3.2. The processes which ensure that the personnel developing, testing and validating the toolchain and its components have appropriate experience, expertise, and training and evidence that these processes are implemented and effective. If there are any activities not directly controlled by the manufacturer, there must be an explanation of measures taken to ensure confidence in the quality and integrity of these activities.
- 2.3.3. A description of the input parameters, along with any uncertainties in the model parameters, which have been used to validate the models included in the tools and toolchain. The manufacturer should also provide documentation demonstrating that the data used to validate the models covers the intended scope and functionality of the toolchain.
- 2.3.4. A description of the overall approach to data management.
- 2.3.5. A description of the management activities which describe the modifications between toolchain releases, version control and the review processes to ensure those modifications result in a toolchain that is still suitable, i.e. meets the criteria in 1.1.1.
- 2.3.6. Description and analysis of toolchain and components
- 2.3.6.1. All parts of the toolchain, tools and models shall be described by the manufacturer.
- 2.3.6.2. The vehicle manufacturer shall define the validity domain on which the toolchain will be applicable and how the validity domain has been derived including any AEBS performance influencing factors, parameter ranges, assumptions, limitations and tolerances.
- 2.3.6.3. The documentation shall include a description of the key performance indicators which will be assessed during validation, such as time to collision, remaining distance or impact speed.
- 2.3.6.4. The documentation shall include a description of the accuracy requirements for the toolchain and its components, including comparison with physical tests.
- 2.3.6.5. The documentation of the toolchain shall include assumptions, limitations, uncertainties and the necessary levels of fidelity.

- 2.3.6.6. The manufacturer shall provide a description of the toolchain assessment methodology, including the impact of any errors and uncertainties on the results and the subsequent consequences for the compliance of the system with this regulation.
- 2.3.7. The manufacturer should review the information produced in addressing the requirements of paragraph 2.3.6.2. and document any implications for the use of the toolchain.
- 2.4. Verification
- 2.4.1. ~~The toolchain and its components models that are developed and tested shall be capable of accurately representing the relevant aspects of the physical AEBS that is being modelled. that is being modelled. The models are used in tools and the tools are incorporated into toolchains which emulate the overall physical behaviour of AEBS with the appropriate quality within the declared domain of validity.~~
- 2.4.2. ~~The manufacturer shall provide documentation on the AEBS function code verification which demonstrates the numerical and logical implementation of the toolchain and its components is correct. They shall also provide documentation showing the variation of input parameters was sufficiently wide to identify combinations for which the toolchain or any of its components show unstable or unrealistic behaviour.~~
- The manufacturer shall provide documentation on the verification activity of the modelling that implements the AEBS function in the toolchain and its components. This shall include a description of the models, their implementation, how they represent the AEBS function and a description of the activities that have been performed to confirm that the models have been correctly implemented.
- 2.4.3. The manufacturer shall provide an estimation of the numerical errors affecting the toolchain and its components and analysis that the errors remain sufficiently bounded.
- 2.4.4. The manufacturer shall demonstrate the effect of variations of the model parameters on the output values and identification of the most critical parameters which will influence the results. This shall also include a robust calibration procedure for these parameters.
- 2.4.5. ~~Simulation model~~ Validation process
- 2.5.1. ~~The simulation model shall be validated in comparison with the physical validation tests performed under paragraph 1.2. and comparability of the test results shall be proven.~~ The vehicle manufacturer shall describe their overall approach to validation including performance measures and a validation strategy. The validation strategy shall be agreed by the Type Approval Authority or its technical service, including the number of physical tests used to demonstrate that the toolchain is an accurate representation of the physical system. The number of tests performed shall ensure a statistical comparison between physical and simulation results is possible.
- 2.5.2. The validation strategy shall be ~~based on scientific methods~~, defined by the ~~car~~ manufacturer and presented to ~~agreed with~~ the Type Approval Authority ~~and~~ or its technical service for review and agreement.
- 2.5.3. ~~For the validation~~, The manufacturer shall demonstrate how the toolchain achieves the key performance indicators ~~shall be assessed~~ defined in paragraph 2.3.6.3. and accuracy requirements defined in paragraph 2.3.6.4. This shall include justification for the choice of key performance indicators and accuracy requirements, and what the criteria is for a successful assessment, such as measures of performance and goodness of fit.
- 2.5.4. The manufacturer shall provide the list of validation scenarios. The manufacturer shall provide the parameter descriptions and accuracy requirements that were needed to perform the validation tests.

- 2.5.5. The manufacturer shall provide documentation describing the validation that was performed to establish the credibility of the toolchain. This shall include information related to the processes that were followed, physical tests that were performed and models and tools that were used.
- 2.5.6. The manufacturer shall provide documentation that demonstrates how they have characterised the uncertainty in the input data and evaluated the model parameters. The overall uncertainty of the results shall be quantified based on the toolchain structure and from the data and its flow through the toolchain. This uncertainty quantification should allow estimates of the likely errors and the required safety margins that should be applied to the results when the toolchain is used for virtual testing.
- 2.5.7. At the request of the Type Approval Authority or its technical service, in addition to the documentation provided by the vehicle manufacturer, additional confirmatory validation, which shall include physical tests, shall be performed or witnessed to confirm the accuracy between the physical and the simulation results. These tests may be relevant to the entire toolchain, specific parts of the toolchain or any of its components.
- 2.5.8. The number of physical tests to be tested shall be defined in agreement between the manufacturer and the Type Approval Authority or its technical service. in order to They shall be sufficiently to cover the validity domain specified by the vehicle manufacturer.
- 2.5.9. The methodology used to generate physical validation data, such as data recording equipment, data processing, calculation of scalar values shall be documented in the simulation report as part of the validation documentation. The output and results of the toolchain and its components shall be compared against these physical tests and the appropriate assessment criteria.
- ~~1.5. Additional data and information~~
- ~~For this application, the following information shall be supplied to the approval authority and technical service in addition to the data, and drawings listed in paragraph 3.2. of this Regulation.~~
- ~~1.5.1. A description of the applied simulation and calculation method which has been used such as identification of the model, the analysis software, its producer, its commercial name, the version and contact details of the developer.~~
- ~~1.5.2. A description of the input parameters.~~
- ~~1.5.3. A description of the validity domain taking into account AEBS performance influencing factors.~~
- ~~1.5.4. All parts of the simulation toolchain such as interlinked simulation modules and tools shall be described by the manufacturer.~~
- ~~1.5.6. A description of the data management archiving system shall be provided by the manufacturer.~~
- ~~1.5.7. A description of the versions control and the review processes in case of modification within the simulation toolchain shall be provided by the manufacturer.~~
23. Activity 2: The use of virtual testing results to conduct testing required for approval process (pillar 2)
- 23.1. Compliance of the Advanced Emergency Braking System with the performance requirements as defined in paragraphs 5.2.1 to 5.2.3. of this Regulation may be demonstrated by the vehicle manufacturer to the Type Approval Authority or its Technical Service by making use of virtual testing of the dynamic manoeuvres described in of the paragraph(s) 6.45. to 6.7. of this Regulation.
- 23.2. All simulation-virtual testing results provided by the manufacturer in applying for an approval in accordance with paragraph 4. of this regulation shall refer

to the **method toolchain** evaluated and validated according to paragraph 1. of this annex.

~~2.3. Additional data and information~~

~~For this application, the following information shall be supplied to the technical service in addition to the data, and drawings listed in paragraph 3.2. of this Regulation.~~

~~2.3.1. A description of the applied simulation method which has been used such as identification of model, the analysis software, its producer, its commercial name, the version and contact details of the developer.~~

~~2.3.2. A description of the input parameters.~~

~~2.3.3. A reference to the validated simulation method used in application of paragraph 1 of the current annex.~~

~~2.3.4. All parts of the simulation toolchain such as interlinked simulation modules and tools shall be described by the manufacturer.~~

3.3. For each approval application the manufacturer shall provide a confirmation that the virtual testing:

- (a) was conducted using a validated toolchain;
- (b) was performed by staff with ~~adapted~~ appropriate competences and skills;
- (c) has been ~~undertaken~~ performing using ~~by~~ a toolchain that has a unique identifier and sufficient information including scope, regulatory applicability and validation history to ensure that there is traceability and assurance that the toolchain is suitable and fit for purpose; and
- (d) has been ~~used~~ performed using a toolchain within its scope and in accordance with any restrictions.”

II. Justification

1. This proposal aims to allow the approval applicant to use virtual testing as an alternative to physical tests. This requires an assessment of the methodology to be used. This approach has been defined in the European Union Whole Vehicle Type Approval (WVTA) regulation and is being further developed by the IWG on Validation Method for Automated Driving (VMAD).

2. Section 1 has been rearranged based on the work in Annex 5 from the VMAD document ECE/TRANS/WP.29/2024/39 – Virtual testing and credibility assessment. The previous proposal (ECE/TRANS/WP.29/GRVA/2024/19) lacked sufficient coverage and detail of the topics that VMAD had identified as being necessary to ensure a robust approach to the use of Modelling and Simulation. The new structure also ensures that the concept of the toolchain assessment and the virtual testing activity are distinct.

3. A new section on verification has been added (2.4), which is a key component of robust modelling and simulation development. Its inclusion provides assurance that the models and tools have been developed and implemented correctly.

4. The section on validation previously lacked detail about the requirements for validation, and the strategy and the documentation that supports this. This section now requires the manufacturer to provide documentation for the overarching strategy, performance, acceptance criteria, scenarios and evidence that demonstrates that the validation has been successfully undertaken.

5. The purpose of section 3 is to identify the activity associated with using the accepted toolchain to perform virtual testing. It now ensures that the manufacturer includes a clear statement about the toolchain and that it is fit for purpose to undertake virtual testing and that the virtual testing results are traceable to a validated toolchain.

6. This proposal defines a practical approach to anchor the main safety relevant principles whilst giving flexibility to the applicant in selecting the virtual tools to be used.

7. An example of the application is presented in informal document GRVA-15-20.