From the limited to a full revision of the Noise TSI
Presentation of simplified evaluation methods for the verification of conformity

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The limited revision of the Conventional Rail Noise Technical Specificati

The limited revision of the NOI TSI launched by ERA in 2009 aimed at simplifying and reducing the costs of the acceptance process of railway units related to the noise emission. In particular the following main items were identified in the work programme of the NOI TSI working party:

- the procurement of a reference track available in every MS in a non discriminatory way, and
- an introduction of some flexibility in the general assessment process, such as making use of calculation methods as a complement to measurements, making use of comparable analysis to a known type.

The following issues were not in the agenda of the limited revision:

- Technical scope (type of rolling stock, specified noise cases...),
- Extension of the geographical scope,
- Targets and noise limits,
- Definition of the reference track requirements to the rail roughness and track decay rates.

The main changes brought by the limited revision of the NOI TSI

Modification of the test conditions for the verification of pass-by noise requirements

One of the major changes of the revised NOI TSI is that it is now permitted to carry out tests on a track that does not comply with Annex A (TSI reference track), as long as the measured noise values remain within the limits. This novelty supports a reduction of the measurement costs for performing rolling stock noise tests.

This leads to a two-step approach described in figure 1, where the certification of a unit is decoupled from quality of the test result:

- The first step consists in the comparison of the noise emission value measured on a certain track with the noise limit. The main difference with the former process is that any track can be used to perform the noise tests. As long as the rolling-stock meets the noise limits it complies with the TSI and must not be imperatively tested on a reference track.
- The second step is related to the classification of the noise value as comparable or not to other measured noise emission values. In particular, the comparability of noise values is stated when the acoustic tests are carried out on a reference track. To make this assessment of track compliance
more flexible, a “small deviation method”\(^1\) [3], has been especially developed and implemented. It enlarges the number of tracks which can be considered as suitable for producing comparable noise values with a controlled loss of accuracy. The comparability of the noise values between rolling stocks is an important condition for the opening of the railway market and will be later used by ERA to set future more stringent noise limits.

In any case, this process does lead to correct measured noise values which are compared to the limits. The only calculation step may concern the assessment of comparability.

![Diagram](image.png)

**Figure 1** — Chart of the pass-by noise certification process pursuant to the revised NOI TSI

**Input of the standardisation work**

The limited revision of the NOI TSI takes advantage of European standards especially developed or revised by CEN\(^2\) with a mandate of the AEIF\(^3\): EN 15610 [4] dealing with the measurement of the acoustic rail roughness and EN 15461 [5] dealing with the measurement of track decay rates are quoted in the TSI and replace the former annexes A1.4 and A2. Moreover relevant parts of the project of revised standard prENISO3095:2010 [6], specifying the measurement of noise emission of railway vehicles have been taken over in annexes of the revised NOI TSI. Though this latter project of standard was not yet finalised, some enhancements such as the small deviation method, the simplification of stationary measurements procedure, the clarification of the vehicle conditions, the relaxation of weather and track conditions, etc. were considered worth enough to be implemented in the TSI.

A fourth standard, FprEN15892 [7] focusing on the measurement of cab noise and also especially developed for TSI purposes, was finally not quoted due to the difficulty to change matters related to noise in working conditions in the very tight time schedule allocated to the limited revision.

**Introduction of the concept of “simplified evaluation method” in the verification process**

The other major change of the revised NOI TSI is provided by the new section 6.2.3 dealing with the verification methods specific to noise aspects of rolling stock. Instead of the test procedures set out in section 4 of the TSI, it is now permitted to substitute some or all of the tests for a simplified evaluation method. According to the NOI TSI the simplified evaluation method relies on an “acoustical comparison of the type under assessment to an existing type with documented noise characteristics compliant with the noise TSI; the latter is further referred to as the reference type”. The simplified evaluation on a unit shall consist of providing evidence to show that the acoustically relevant systems

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\(^1\) This method is described in the revised NOI TSI [1] and is applied to the rail acoustic roughness parameter. Some improvements showed this was also applicable to the Track Decay Rate parameter of the track [3]

\(^2\) Comité Européen de Normalisation (European Committee for Standardization)

\(^3\) Association Européenne pour l’Interopérabilité Ferroviaire (European Association for Railway Interoperability)
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and characteristics are either identical to those of the reference type, or such that they will not result in higher noise emission of the unit under assessment.

The simplified method concerns the following configurations:

- Different formations of multiple units (e.g. trainset with 3, 4 or 5 coaches)
- Renewed or upgraded units
- Vehicle family i.e. units which are largely based on an existing design

It can be implemented for each of the specified noise item separately: stationary noise, starting noise, cab noise and pass-by noise.

This new input settles the principle that the demonstration of the proof for conformity might be brought by calculation means instead of measurements, and therefore have a positive impact on costs. However this method is not explicitly developed in the limited revision of the NOI TSI.

Requirements to a certification method mixing measurements and calculations

The growing interest in the use of calculation within the acoustic acceptance process relies on the axiom that simulations are cheaper and quicker than tests. However, the complexity and degree of accuracy of the acoustics predictions makes it inconceivable a virtual homologation of a completely new vehicle for the time being. The current trend, in the field of the acoustic certification, is then to focus on hybrid methods taking advantage of measurements and introducing progressively steps of calculations. During the limited revision of the NOI TSI, ERA took the plunge by introducing the concept of "simplified evaluation" without specifying it in details. It might be therefore hardly applicable for Notified Bodies (NoBo).

Such a simplified method needs to be shared by the sector, should be univocal and not interpretable from a technical point of view. The following lines aim at proposing the minimal requirements which such an evaluation should fulfil to be suitable for use in a certification frame (a parallel is made with the requirements to test procedures stated in EN ISO IEC 17025 [8]):

a) The calculation method should be:

- Validated for the range of application of interest of the relevant parameters i.e. train speed, frequency, acoustic rail roughness, etc.,
- Described in details in order to enable a verification of its correct application by a NoBo,
- Harmonised between the different actors (as stated for the noise mapping by the European Noise Directive) and preferably standardized. The examples of Eurocodes for the action on structure to prove the conformity of buildings, bridges, tunnels... to a European directive demonstrate the feasibility and give the way. In the railway acoustic field, annex E of the EN13979-1 [9] already proposes an assessment of the acoustic behaviour of monobloc wheels by means of calculation and/or measurement.

b) The corresponding software where the method is implemented should also satisfy some requirements: in France for instance, the technical description of the software used for the noise prediction of ground transportation should comply with the standard NF S 31-131 [10]. The requirements concern the description of:

- the method and formulae used,
- the precision and the validity range,
- the limits for the use of the software,

The standard NF S 31-133 also prescribes an approach for the validation of the programming and defines a list of test cases to be carried out.

c) The entity in charge of carrying out the calculations should at last comply with some requirements regarding their competence and expertise. The RFU STR 22 [11] provided by NB-Rail on its website addresses the criteria applying to testing bodies involved in the certification process.

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4 Co-ordination group of Notified Bodies for railway products and systems
According to [11] a testing unit shall be accredited against EN ISO/IEC 17025. Alternatively it lists a series of criteria to be fulfilled by non-accredited testing units concerning among other the test facilities, the quality system pursuant EN ISO 9001 [12], the technical expertise and an appropriate training of the staff as well as the test report content. It is the responsibility of the NoBo to conduct periodic audits in order to verify the correct application of these requirements. Hence there is a need to extend the scope of the RFU STR 22 to entities in charge of conducting calculation or laboratory tests other than those prescribed in the current NOI TSI in order to ensure an equivalent quality of the calculation and test results.

Review of applicable methods suitable for the simplified evaluation

Introduction

This section aims at assessing different methods currently available, which fulfil the conditions listed above, and which would be applicable by the Notified Bodies immediately after the entry into force of the revised NOI TSI.

At first, the importance of the acoustic description of the unit type is highlighted, and then possible approaches are discussed for each of the three configurations of rolling stock for which a simplified method may be applied to prove the conformity with the four noise items specified in the NOI TSI.

The acoustic description of the unit type as a key issue

In this context the acoustic description of the reference type becomes a key issue since the simplified evaluation method can be actually considered as being an evaluation of the noise impact of a modification of a certain reference type. Thereby the first step of an evaluation procedure would consist in checking whether a certain change affects the acoustic behaviour of the reference type at all. This presupposes the existence of an exhaustive description of the noise relevant constituents and characteristics. Since the NOI TSI doesn’t give any further specification on this matter one can refer to the recommendation for use RFU RST 027 [13] provided by NB-Rail. This RFU-RST-027 should be simplified and completed with some missing items such as e.g. the software controlling traction units and auxiliaries.

Stationary noise

a) Formations of multiple units

The new measurement procedure of stationary noise described in appendix C of the TSI and adapted from the new prEN ISO 3095:2010 clearly aims at reducing the measurement effort for platforms of multiple units. Contrary to the former versions of the EN ISO 3095 standard [14], the distribution of the measuring positions now focuses on each vehicle within the fixed formation. Thus it is now possible to calculate the noise emission of one vehicle only. Moreover the new method specifies that when the same vehicle is present several times within the unit, it is sufficient to measure it once and to use the measurement results obtained at the equivalent positions to calculate the overall noise level of the unit.

In analogy these precepts may be transposed to the certification of different formations of multiple units, since a platform usually consists of different combinations of a certain number of vehicles. Thus, provided that each of the vehicles has been measured once, it is possible to predict the stationary noise of all the combinations.

Figure 2 presents a simple application case where the reference unit, for which a full set of measurement results is available, is composed of three vehicles of the type A, B and C. This configuration has already been certified according to NOI TSI. In a second step the manufacturer would like to certify a new batch based on the same platform but including the vehicle B twice. The stationary noise emission of this new type of unit can be calculated from the available measurements data as follows.

The noise levels $L_{Aeq,T}$ measured at all positions $i$ shall be energy averaged to calculate a single noise indicator representative of the unit:

$$\left\langle L_{Aeq,T} \right\rangle_{unit} = 10 \cdot \lg \left( \sum_{i=1}^{n} \frac{L_{A_{eq,T}}}{l_{i,e}} \right)$$

(1)
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where:

$L_{\text{eq},T}$ is the sound pressure level measured at the measurement position $i$

$n$ is the number of measurement positions.

$l_i$ : length associated with the measurement position $i$

The $n$ measurement positions used in the summation shall correspond to the whole mesh defined in Figure 2. Thereby the noise levels of measured equivalent points from vehicle type B shall be considered twice.

While applying the method described above attention must be paid on any acoustical contamination of the noise levels measured at both extremities of the coach B by relevant noise sources located in the adjacent vehicles. Such a boundary effect would lead to an overestimation of the calculated level of the investigated configuration.

Reference:
A-B-C

Variation:
A-B-B-C

Figure 2 — Simple case of a simplified evaluation method applied to two different formations of multiple units based on the same platform.

b) Renewal or upgrading

There is a vast spectrum of cases of renewal or upgrading of railway vehicles going from the exchange of an auxiliary such as a cooling fan, e.g. due to a change of supplier, until a replacement of a diesel traction engine by a more powerful one.

One of the possible approaches would be to manage the noise issue by comparing measurement results, generally of sound power level, obtained in laboratory to prove that the new equipment is more silent than the reference. The commonly applied test procedure is described in the standard EN ISO 3744 [15]. This method is convenient since it allows for qualifying the component alone without needing any prototype of the retrofitted unit.

However from a procedural point of view NOI TSI explicitly specifies in section 6.1. that the concept of interoperability constituent is not applicable to this TSI. Consequently the certification process of the Rolling-stock refers to the entire subsystem and not to single constituents. On the technical side, the main disadvantage of the lab test is that it does not take the integration of the component within the unit and potential structure-borne noise into account.

Therefore it is advisable to always measure new components in the unit under representative operating conditions to guarantee an objective assessment of their direct as well as indirect noise emission. Nevertheless it may be sufficient in many cases to limit the measurements only to the few positions affected by the modifications and to calculate the noise level of the retrofitted unit according to formula (1) by mixing measurement results on the reference and modified unit.
c) **Vehicle family**

For vehicle families the same arguments apply as for the renewed or upgraded units. As soon as a modification of the reference type affects at least one of the noise relevant components then a measurement under mounted conditions shall be repeated.

**Starting noise**

The use of a simplified procedure to assess the starting noise is challenging. This is due to the test procedure under which the reference unit has to be measured on the one hand and to the specified indicator, the A-weighted maximum sound pressure level $L_{pA_{\text{max}}}$ on the other hand. As shown in Figure 3 the starting noise shall be measured at one position 10 m ahead of the front of the unit and at further positions along the unit when it is longer than 50 m. The test procedure specifies that the train shall accelerate from standstill up to 30 km/h and then maintain the speed.

According to this the maximum noise level measured during the test strongly depends on two factors: the instant and the regime at which the dominating noise source passes the microphone(s). For these reasons the starting noise level can hardly be predicted with sufficient accuracy.

![Figure 3 — Measurement positions for acceleration tests](image)

In the course of the revision of the EN ISO 3095, Alstom Transportation Germany organised a field test at its production site in Salzgitter in order to optimise the starting noise test and procedure. A new method, called "averaged level method" and described as an alternative to the "maximum level method" in the revised prEN ISO 3095 standard, proposes to shift the measurement distance from the track axis from 7.5 m to 25 m and to replace the indicator $L_{pA_{\text{max}}}$ by an equivalent noise level averaged over the whole starting phase $L_{pA_{\text{eq},T}}$. This procedure is expected to be more robust than the present one in terms of dispersion of the measurement results and easier to simulate in a near future. Once tested at a large extent, and based on results of the return of experience, this "averaged level method" would be a good candidate for an improved starting noise procedure in the frame of the full revision of the CR NOI TSI. In the meantime, no calculation procedure is suitable for a certification process according to the TSI.

**Pass-by noise**

The reduction of the amount of constant speed tests to be carried out is of highest need considering their costs and their impact on the total noise acceptance test time schedule. However their substitution for a simplified evaluation will face high difficulties as a combination of several physical phenomena comes into the picture: aerodynamic, traction and rolling noise may contribute significantly to the overall pass-by noise levels of a unit depending on design parameters such as the type of unit (powered or trailed), the maximum speed, etc.

For freight wagons the case is simpler and a list of cases eligible for a simplified evaluation is already proposed in the NOI TSI (see the list of parameter given in table 7 of [1]). If the listed parameters remain in the acceptable range compared to the reference case, then the renewed or upgraded wagon is deemed to be compliant without testing.
For the other type of units, i.e. coaches, multiple units and on-track machineries, some specific cases of applicable and/or widely accepted simplified evaluation are proposed hereafter:

a) Multi-voltage and dual-mode units

In the case of multi-voltage vehicles or units, the measurements may be limited to the voltage system which is expected to produce the highest noise level. If a unit is designed for AC and DC supply then the AC mode is usually the noisier one. However, in the case of dual-mode vehicles or units (diesel and electric) the measurements shall be performed under both modes. This simplification, which could also be applied to stationary and starting noise tests, was proposed during the enquiry of prENISO3095 and is expected to be implemented in the future published standard.

b) Modification of an auxiliary system

In the case of a modification of the unit limited to the change of an auxiliary system producing exclusively traction noise (e.g.: fans of a cooling system, compressor, etc), the following procedure may be use:

A noise measurement with the vehicle stationary should be carried out at a position directly opposite the component, at 1.2m high and at a distance of 7.5m from the track centreline\(^5\), under the operating conditions that will exist during the pass-by. If the stationary noise level at these conditions remains at least 10 dB below the pass by noise level of the reference unit then it can be assumed that this component does not contribute to the overall noise emission at pass-by and the upgraded unit is deemed to comply with the corresponding pass-by noise limit.

c) Modification of the braking system

Any modification of the braking system may have a major effect on the wheel tread conditions and consequently on the rolling noise emitted by the unit when passing by. In that case, the constant speed test may be skipped and replaced by a calculation procedure based on wheel roughness measurements \([16]\). This implies that both the wheel roughness of the renewed/upgraded unit and of the reference type unit should be measured. The latter shall concern the specific unit which was submitted to the noise test on the reference track.

The proposed procedure calculates an overestimation of the impact of the wheel roughness increase (if any) on the pass-by noise levels as follows:

i. Measure wheel roughness of the reference and renewed/upgraded unit;

ii. Calculate the combined roughness of both units using the acoustic rail roughness measured on the reference track;

iii. Calculate the correcting roughness frequency spectrum as the difference between the two combined roughness spectra (only increases are taken into account);

iv. Calculate a revised noise spectrum by adding the correcting roughness spectrum to the measured pass-by noise value of the reference unit;

v. Calculate an overestimation of the noise impact of the modification as the difference between the A-weighted overall noise of the revised and reference spectra;

vi. If this noise impact is less than or equal to 0 dB, the renewed/upgraded unit is considered to fulfill the TSI limits for the corresponding train speed. This compliance shall be examined for one pass-by at each speed.

To support this process, the wheel roughness measurement protocol developed within the NOEMIE project \([17]\) can be used. Though it could be used as a reference specification, the entire procedure should be improved in the frame of a standardization process. Besides, CEN/TC256/WG3\(^6\) identified this issue as a potential high priority work item in its roadmap for the next years.

d) Modification of the wheel type

As for the freight case the use of the EN 13979-1:2009 is proposed as it provides a general procedure for the assessment of the acoustic behaviour of monobloc wheels. This procedure, which relies on the

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\(^5\) Additional measurement positions focusing on specific noise sources within the unit are already introduced in the prEN ISO 3095:2010

\(^6\) Working Group of CEN in charge of the railway noise emission
comparison with a reference wheel, only foresees a full calculation method (based on TWINS theory) for axi-symmetric wheel of standard diameters. The application of this method to more complex wheels shapes (e.g. with small diameters, equipped with dampers, etc) requires a tuning of the wheel modal basis with the help of experimental modal analysis. For even more complex designs such as wheels with holes for disc brake mounting or wheels equipped with screens a full measurement procedure is asked but not specified. A tighter specification of the procedure in the case of noise calculation tuned by experimental data should be developed. The outcomes of the SILENCE projects [18] and especially the deliverable [19] may help.

An alternative way, based on sound power laboratory measurements and representative wheel/rail contact forces may also be considered. The development of corresponding test procedures is one of the tasks of the current DeuFraKo Project Stardamp dealing with the standardisation of validation methods for damping technologies.

e) Modification of the aerodynamics of the unit

At conventional speeds, any modification of the external shape of the unit may have a negligible effect on the total pass-by noise as the aerodynamic noise may become significant only for speeds above 250km/h [20].

![Radome (internet antenna) on the roof of a Thalys](image)

Figure 4 — Radome (internet antenna) on the roof of a Thalys

At high speeds, in most of the cases, the modification of the aerodynamics of the vehicle may not be simulated at acceptable precision and costs. However, when concerning the replacement of the pantograph or the adding of any other roof mounted devices (see e.g. wifi antenna on the Thalys in Figure 4) the field test may be replaced by a measurement campaign in an anechoic wind tunnel (see [21] and [22]). It shall then be demonstrated that the roof equipped with the new features does not generate more noise than the former one. The air flow shall be representative of the actual case and the measurement positions shall take into account the directivity of the noise sources.

f) Modification of the external shape of the unit

Any modifications of the external structure of the unit may lead to a change in the aerodynamic noise. This case relates to e).

The modifications of internal as well as of external structural panel may have an effect on the traction noise by modifying the sound insulation of auxiliaries as well as diffraction and reflection effects. For those cases a similar procedure as for b) should be applied where relevant.

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7 DeuFraKo is a German-French cooperation programme funded by both ministries of economy
*Cab noise*

There are no simple and validated cab noise calculation tools available on the market at this time. The current European R&D project MidMod [23] aims at developing and validating new noise prediction methods with a special focus on the mid-frequency range. Even if most of the issues addressed in MidMod concern the automotive domain a work package deals with interior noise in trains and more specifically with cab-noise in high speed trains with a significant aero-acoustic contribution.

The results of such projects may be applied for the certification of rolling stock in the future but at the moment, the effort necessary to carry out a precise prediction of cab noise is far more complex and expensive than the conduction of noise measurements as prescribed in the NOI TSI. As a consequence the conduction of tests is more worthwhile than calculations.

**Outlook in the needs of future NOI TSI revisions**

*A short term approach: specifications for the simplified method for the verification of conformity*

The definitive scope of the forthcoming full revision of the NOI TSI is not yet completely known but it would at least include the following critical issues already mentioned in the §7.2. of the revised NOI TSI: second step limit values for pass-by noise and possibly for starting noise, inclusion of the infrastructure in the scope of this TSI and inclusion of a monitoring scheme for wheel defects. This mandate is ambitious and does not take account of the necessity to improve the definition of new calculation scheme for the verification of conformity yet.

As far as the verification process is concerned, the emphasis should then be put on a more detailed specification of the simplified verification procedure. At this stage, no correction of the measured noise values to be compared to the NOI TSI limits should be allowed.

*A middle term approach: towards a virtual homologation scheme*

The larger use of calculation methods in the acceptance scheme, as proposed in the limited revision of the NOI TSI has also raised the idea that an acceptance process could progressively be endorsed by calculations in the future. Thereby the main issue should be to tackle the precision of calculation tools which should be at least equivalent to existing methods based on measurements. At this stage, field test measurements will probably still be necessary but the measured noise values may be corrected to an ideal reference case before the comparison with TSI noise limits.

The aim pursued by the introduction of calculation in the acceptance scheme is twofold:

- On the one hand, a simplification of the measurements conditions, especially for pass-by tests. A simulation process would enable to derive pass-by noise values of a unit on a reference track from measured values on any track or at least on a track with rail roughness levels and track decay rates laying in a range for which the correction procedure is validated. The reference track would then become a virtual concept only used to set the noise limits. Thus the comparability of all noise measurements would be improved and it could be conceivable to define a reference track representative of the European network. The current reference track is the result of a compromise between characteristics of existing operational tracks and of a perfectly quiet track. The following figure, as an echo to Figure 1, shows what could be the principle of such a virtual homologation.

- On the other hand, calculations may help to widen the range of configurations specified in the NOI TSI: in particular, different auxiliary conditions, train speeds and track conditions may be simulated. In the same way, the statistical variability of noise sources due to the manufacturing process may be assessed to make the noise type test more representative of normal operations. Such enhancements could provide the connection between the NOI TSI and the needs of accurate railway noise source input data for noise mapping asked by END Directive [24] often requested by the sector.

These aims will require the definition of a mixed approach combining advanced measurement methods and improved simulation tools.

At first experimental noise source characterization and separation techniques (aerodynamic vs. rolling noise, but also track vs. wheel sources, see [25] & [26]) should be implemented to collect detailed noise data during the measurement campaign carried out on the reference vehicle type. These methods should probably rely on prior knowledge/database on typical railway noise sources to allow
the identification of relative noise contributions in an engineering grade process (e.g. simplified rolling noise calculations).

Then, collected noise data will feed calculation models for further simulations of other configurations of units and/or operating conditions. Such tools, developed in the frame of R&D projects, already exists (see e.g. Erreur ! Source du renvoi introuvable.) but should be improved in terms of at least propagation model and interaction between the train structure and the onboard noise sources (diffraction, insulation effects) before a virtual acoustic homologation could be envisaged.

Once developed and validated, these experimental and numerical tools will allow enlarging the scope of the simplified evaluation, the requirement of reference unit type testing being limited only to innovative trains for which no relevant data are available.

Figure 5 — Conceivable certification process for pass-by noise at midterm

Conclusion
This review shows the long way to future revisions of the NOI TSI, addressing both:
- The recommendations expressed in 2005, with explicit demands in terms of a further reduction of noise limits, and
- The efficient application of the new items developed in the limited revision.

In both cases, a large amount of technical issues remains open. They represent a strong demand to the sector, which is requested to provide guidelines, standards as well as short and middle term research work.

This may be at the same time an opportunity for him to improve the environmental friendliness of the railway transport against noise, for the social benefit of the whole member states across Europe. However to reach this target the noise issue must be addressed at European level with corresponding financial support.

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