EC Contract No. FP7 - 284877

Virtual certification of acoustic performance for freight and passenger trains

Deliverable 1.1: CLARIFICATION of the SIMPLIFIED METHOD IN THE PARTIAL REVISION OF THE TSI

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EXECUTIVE SUMMARY

ACOUTRAIN project aims at introducing virtual testing in the TSI certification procedure.

Within that frame, the working group of ACOUTRAIN has been asked, in the first stage of the project, to propose some clarifications about the simplified method mentioned in the present TSI.

Nine different scenarios, where a simplified approach can be foreseen for the TSI certification, have been selected (see Table 1): for each of these cases, a flow diagram has been compiled, detailing the proposed methodology for carrying out a simplified approach for the TSI certification.

These flow diagrams do not represent an exhaustive selection of what could be encountered within the frame of the TSI application. They illustrate common and agreed strategies (among the ACOUTRAIN WP1 partners) for simplified approach implementation.

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1. INTRODUCTION

The ACOUTRAIN project aims at introducing virtual testing in the TSI certification procedure.

Within that frame, the working group of ACOUTRAIN has been asked, in the first stage of the project, to propose some clarifications about the simplified method mentioned in the present TSI [1]. In fact, the application of a "simplified method" could require a basic virtual testing approach, which is a first step for a wider VT implementation.

The following flow diagrams propose some methodologies to carry out a certification with a simplified method. The cases were selected according to the working group ACOUTRAIN WP1 **and they do not represent an exhaustive selection of what could be encountered within the frame of the TSI application**. The type of rolling stock to which the method is applicable will be mentioned in each dedicated flow diagram.

The certification cases described are the following:

Modification of	Stationary	Pass-by	Starting noise
Number of axles per unit length	Not relevant	Flow diagram n°1	
Maximum speed	Not relevant	Flow diagram n°2	Not re levant
Modification of wheels	Not relevant	Flow diagram n°3	Flow diagram n°3
Brake system	Not relevant	Flow diagram n°4	Flow diagram n°4
Formation of multiple single cars	Flow diagram n°5	Flow diagram n° 6 (addition of a single car) Flow diagram n°7 (removal of a single car)	
Same family / EMU-DMU (worst case selection)	Flow diagram n°8	Flow diagram n°8	Flow diagram n° 8
Equipment (i.e. traction equipment or auxiliary system) / installation of equipment	Flow diagram n°9	Flow diagram n°9	Flow diagram n° 9

Table 1: Application cases for which a simplified method is proposed and detailed in flow charts

2. GENERAL REMARKS

The proposed flowcharts can **only manage one modification at a time.** However, in many situations, several modifications have to be handled together. The following approaches can be proposed to manage several modifications:

- If the concerned modifications cause a reduction in noise level in comparison to the reference, these positive effects can be considered as cumulative,
- If one or more of the modifications cause a higher noise level than the reference, the future ACOUTRAIN final VT process to be described in the deliverable 1.8: "a virtual certification process", should be applied.
- Alternatively, measurement tests may be carried out

Moreover, the reference rolling stock must have been certified according to a full experimental process according to the requirements of the present TSI. The reference rolling stock should not be a rolling stock certified according to a simplified approach.

When it is mentioned at the end of a flowchart that "**a simplified approach is not applicable**", the ACOUTRAIN partners propose either to carry out the measurements advocated by the TSI technical recommendations or to apply the Virtual Testing procedure that will be described in the ACOUTRAIN deliverable 1.8.

Note: Each time that a measurement is advocated, it should be carried out according to the standards mentioned in the TSI. When no standard is specified in the TSI, the current harmonized standards shall be applied. Approximations and additional measurements that are implemented in the proposed methods are associated with a certain uncertainty. This should be kept in mind when evaluating the results. The more modifications the larger the uncertainty of the results in relation to the reference system may become. It is uncritical in the case that the modifications lead to a significant noise reduction. If only small differences are observed more than one modification at the time should be handled with caution.

2.1 ACOUSTIC DEFINITION OF A ROLLING STOCK

The simplified method can be used in the certification process if the rolling stock is precisely described in term of acoustics. In the following the term "reference rolling stock" corresponds to a TSI approved RS; the term equipment corresponds to traction equipment or auxiliary system.

A complete description of the unit and its sound sources is necessary:

- RFU RST 027 is one option for doing so [3]
- The table shall be filled completely for the reference unit of a RS family and then only the deviation from the reference case shall be specified
- In this list (from the RFU RST 027), the most influential parameters of each equipment that have an impact on its noise level shall be identified
- Clear links shall be indicated between all the equipments (if a modification of one equipment has an impact on the behaviour of another one, it shall be mentioned)

It should be verified that the change in the directivity between the reference and the new equipment should not affect adversely the level at the receiver points. This can be assessed/ derived from ISO 3744 measurements: sound power from pressure measurement in free field, or ISO 9614 measurements: sound power from intensity measurement or by calculation or measurement at (7.5m; 1.2m).

2.2 CERTIFIED TOOLS / CALCULATION OF UNCERTAINTIES

In the following, the terms "certified tools" refers to software certified according to the procedure to be developed in the ACOUTRAIN WP4: deliverable 4.6.

In the following, calculations/measurements of uncertainties are required. They should be assessed according to:

- EN ISO 3095-2012 Annex E for the characterization of measurement uncertainties (or ISO 5725)

- The methodology proposed in the ACOUTRAIN WP5 task 2 / WP1 task 3 for the characterization of uncertainties based on numerical simulations. This methodology will be based on the principle of uncertainty/variability propagation through deterministic software, considering that the uncertainties of the input are assessed.

In some cases, uncertainty can not be characterized. In this case, the ACOUTRAIN partners have decided that a mean uncertainty value equal to 0.5dB can be considered .Therefore, taking into account this limit of uncertainty, we can agree that an increase of noise of 0.5dB is allowed, corresponding to a “reasonable level of uncertainty”.

2.3 VALIDATION STRATEGY

The flow diagrams proposed hereafter should be submitted to informal validation. For most of them, indications are given to justify their reliability, considering either experience of previous cases or analytical justifications. For some others, the validation process should be based on the validation strategy proposed in WP5.

2.4 DEFINITION OF REPRESENTATIVE OPERATING CONDITIONS (ROC)

In case of a replacement of equipment and/or a modification of its installation:

The reference and the new equipment have to be tested under representative operating conditions that are required by the performances of the RS.

These performances are defined by the specifications of the rolling stock (reference and new one).

ROC_{ref} and ROC_{new}

ROC_{ref} have to be defined to ensure that the reference system will provide the required functional performances for the reference rolling stock.

ROC_{new} have to be defined to ensure that the new system will provide the required functional performances for the rolling stock equipped with this new equipment.

In both cases, ROC corresponds for example:

For a thermal engine:

- the engine torque power

For a fan:

- the output air flow at a given load

For electrical converter:

- electrical power

For an HVAC/air conditioning system:

- the cooling performances (heating and cooling conditions)

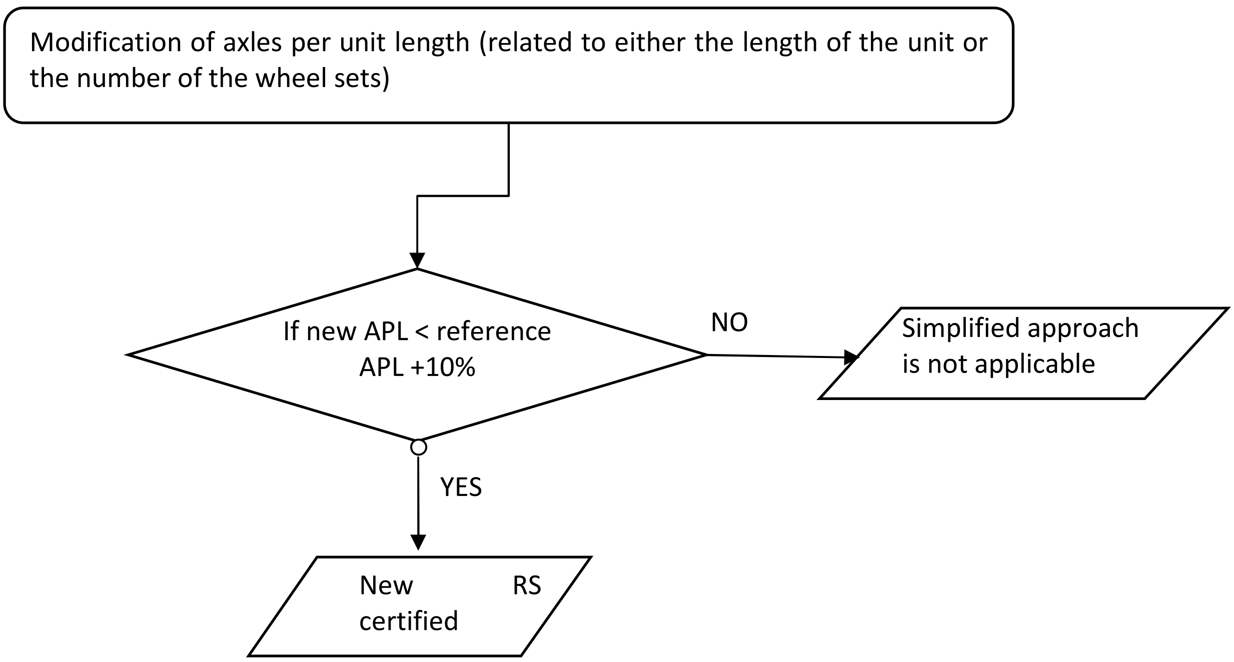
3. FLOWCHARTS

3.1 MODIFICATION OF THE NUMBER OF AXLES

For: EMU/DMU – coaches – Locomotives

In this flow diagram, we propose a simplified method for the certification of a new rolling stock derived from a certified one, but with a different axle-per-unit length number. It both includes modifications of the vehicle length and of the number of wheel sets per vehicle. No modification of equipments contributions (traction equipment or auxiliary) is taken into account.

Care should be taken that the rolling noise is the dominant noise source on the considered rolling stock because the change of the total length may also affect the contribution of the other sources.



Why is this flowchart valid?

According to *Létourneaux & al*. [2], the global pass-by noise is more or less proportional to $10.\log(APL/APL_{new})$.

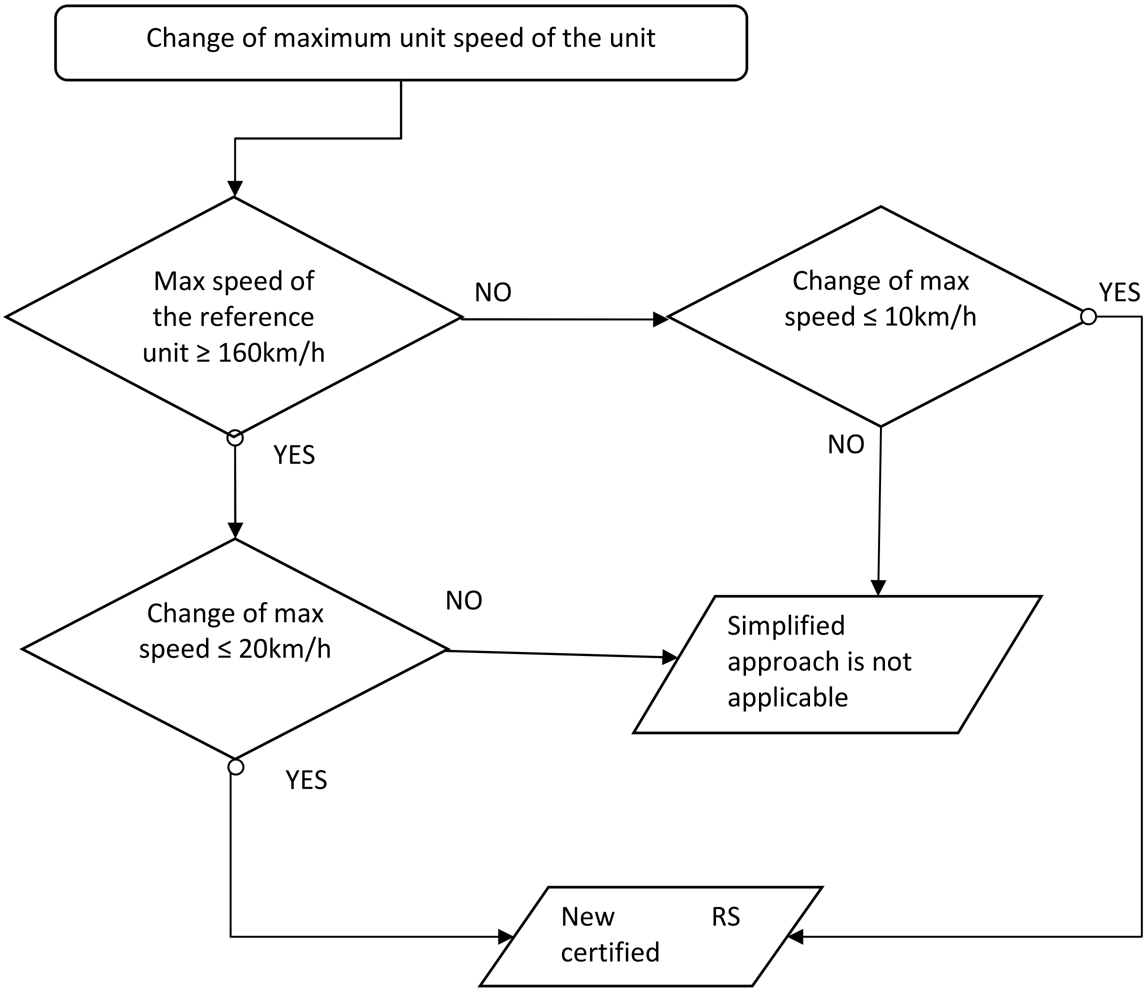
Therefore, for 10% increase of APL, it implies an increase less than 0.5dB, identified as a limit agreed value for an increase of noise.

Special attention should be paid that an increase in length will cause an increase in weight which will affect the contact filter and perhaps the excited frequency range.

3.2 Modification of the unit maximum speed

For: EMU/DMU – coaches – Locomotives

In this flow diagram, we suppose an increase or decrease of the maximum speed of a certified unit. An increase in speed could be occasioned by the exchange to more powerful equipment in which case it has to be verified that the sound power level of these sources did not change.



Why is this flowchart valid?

Changes in maximum speed of less than 20 km/h are unlikely to be applied in practice so the change is expressed in these terms rather than as a percentage. The reason for the limit of 160 km/h is as follows:

It has been decided, considering the reasonable limit of uncertainty, that the change in noise level should be less than 0.5 dB. However, the limit already changes with speed by 30×log(V) below

250 km/h. Recognising that the speed dependence is not exactly $30\times\log(V)$, it is assumed that the *uncertainty* in this speed dependence is less than 10 for speeds below 250 km/h ($(30\pm10)\mathrm{x}\log(V)$) and less than 15 ($(30\pm15)\mathrm{x}\log(V)$) for speeds above this.

For a reference vehicle with a maximum speed of 160 km/h, $10\times\log(180/160) = 0.5$ dB.

For reference maximum speeds lower than 160 km/h, $10\times\log([V+20]/V) > 0.5$ dB, while for higher reference speeds the change is smaller than 0.5 dB. Similarly, for a reference vehicle with a maximum speed of 250 km/h, $15\times\log(270/250) = 0.5$ dB.

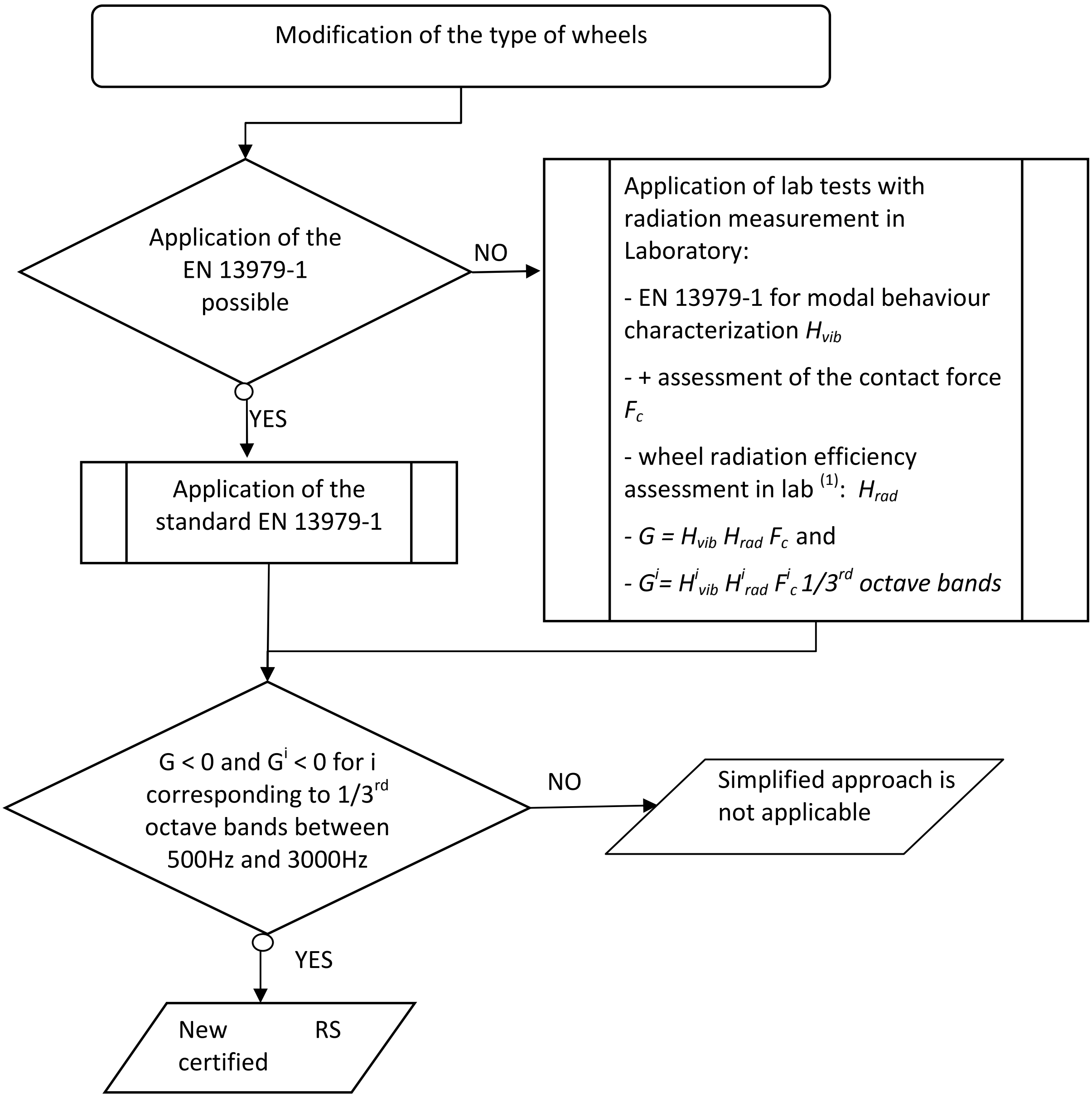
Alternatively, a change in speed of 10km/h leads to $10\times\log([V\times1.10]/V) = 0.4$ dB. This could be used as the limit for reference speeds less than 160 km/h.

3.3 Modification of the type of the wheels

For: EMU/DMU – coaches – Locomotives

This flow diagram corresponds to an exchange of wheel type also including types that aren't covered by the EN13979-1 (2004) [4] application. The scope of EN13979-1 is also widened to the powered wheels. A step forward is made compared to the application cases mentioned in the EN13979-1 as we authorize non monobloc wheels to be considered.

The TWINS calculations should be carried out with the combined roughness equal to the TSI rail roughness. For the track properties: any TSI compliant track could be used.



(1) The radiation efficiency measurement could be carried out with an intensimetry measurement, according to the ISO 9614 [5] for example.

According to EN13979-1: $G = L_{W_{opt}} - L_{W_{ref}}$ where L_{Wopt} is the global rolling noise level of the new wheel and L_{Wref} the global rolling noise level for the reference wheel.

$G^i = L^i{}_{W_{opt}} - L^i{}_{W_{ref}}$ where *i* represents the index of the third octave band considered.

Why is this flowchart valid? How to interpret it?

This procedure is mainly based on the protocol described in the EN 13979-1. The extension of this process (to allow non monobloc wheels) is derived from laboratory methods developed in the IRSID research group (Institut de Recherche de la SIDerurgie – Research institute on steel industry) by Valdunes and INSA laboratory. This method has not been fully validated and requires a good know-how of the user, particularly concerning the wheel radiation efficiency measurement. It should be used with caution.

SIEMENS has already applied the EN 13979-1 procedure for a monobloc wheel with and without noise absorbers (dampers) in the frame of a TSI noise rolling stock assessment. The wheel equipped with dampers was characterized with an experimental modal analysis. Both types of wheels were numerically modelled to carry out a numerical modal analysis: its output was used as an input for TWINS calculations. The simulations with TWINS were carried out with a TSI rail limit roughness and a standard wheel roughness.

The global noise levels produced by both wheels were compared and the damped wheels were declared as less noisy.

3.4 MODIFICATION OF THE BRAKE SYSTEM (THAT DOES NOT INFLUENCE ANYTHING ELSE THAN THE ROUGHNESS OF THE WHEEL)

For: EMU/DMU – Coaches – Locomotives

The brake system could have an impact on the roughness of the wheel. For some brake systems such as disc brake, no influence is noticed on the wheel roughness but could influence the damping of the wheel.

In this flow diagram, we consider a change of brake system that will influence the roughness of the wheels and that does not influence anything else than this roughness i.e. the brake system should not influence other noise parameters than the roughness of the wheels (no change of complete bogie; no change of wheel damping for example).

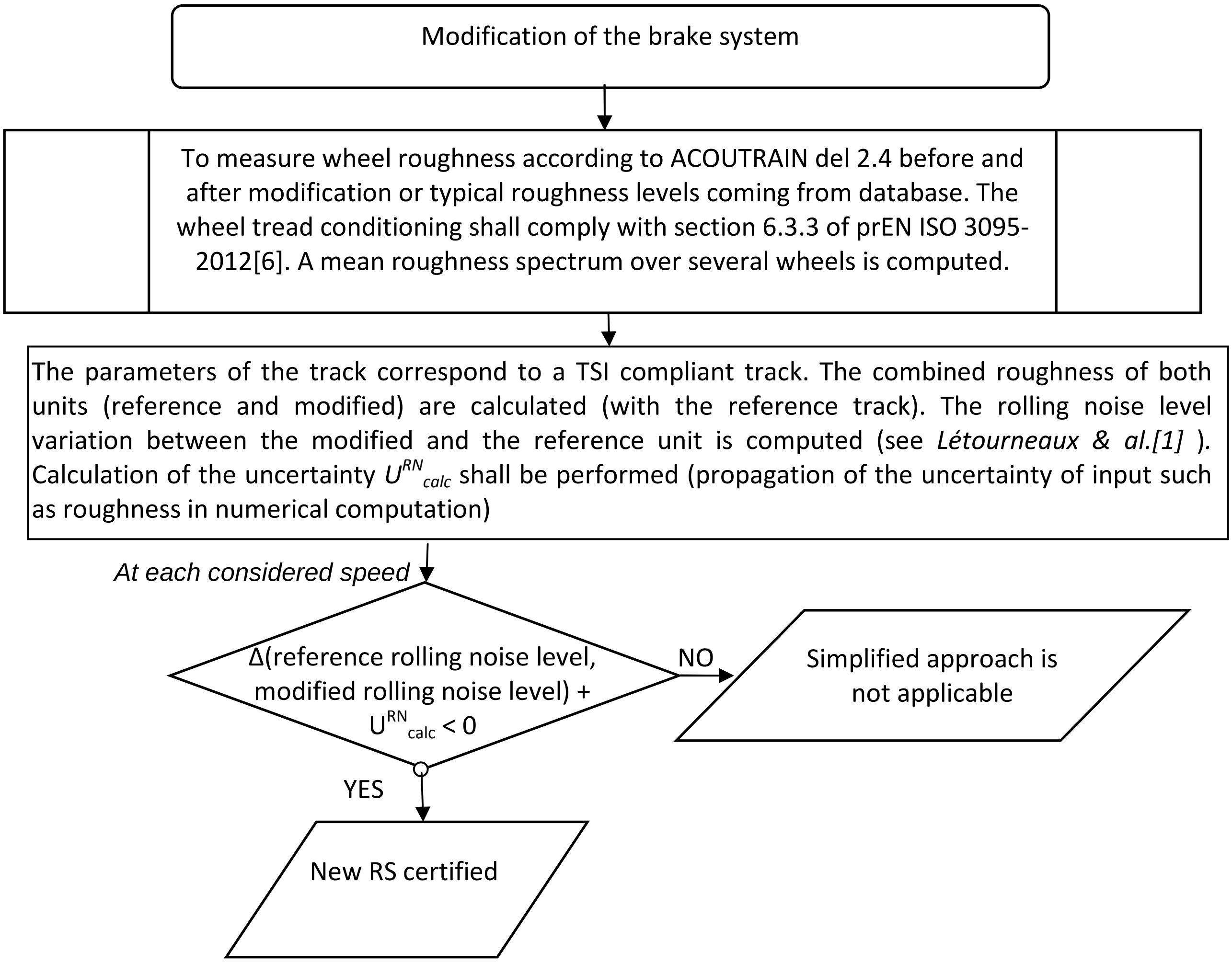
First, we determine if this brake system modification implies an increase or a decrease of the rolling noise:

- If a decrease is found, then, the rolling stock is certified.
- If an increase is found, the contribution of the rolling noise to the global pass-by noise of the RS has to be assessed, with a certified software (according to del 1.8 definition) that can simulate the global pass-by noise

The process described here is not relevant for the cases already covered by the TSI (change of cast iron blocks to composite blocks for example).

Moreover, provided that the wheel roughness spectrum does not exceed the existing one or implies an increase less or equal to 0.5dB on the global pass-by noise, the new RS is certified.

The wheel roughness should be measured according to the procedure described in the deliverable 2.4, considering that the number of wheels that should be measured is not completely fixed, and characterization of the uncertainty of wheel measurement should be required.



Why is this flowchart valid?

In [2], Létourneaux & al. proposes the following procedure, based on the assumption that rolling noise is dominating in the pass-by global noise level and therefore the changes in rolling noise level could directly be transposed into changes in the global pass-by noise:

"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 fulfil the TSI limits for the corresponding train speed .This compliance shall be examined for one pass-by at each speed."

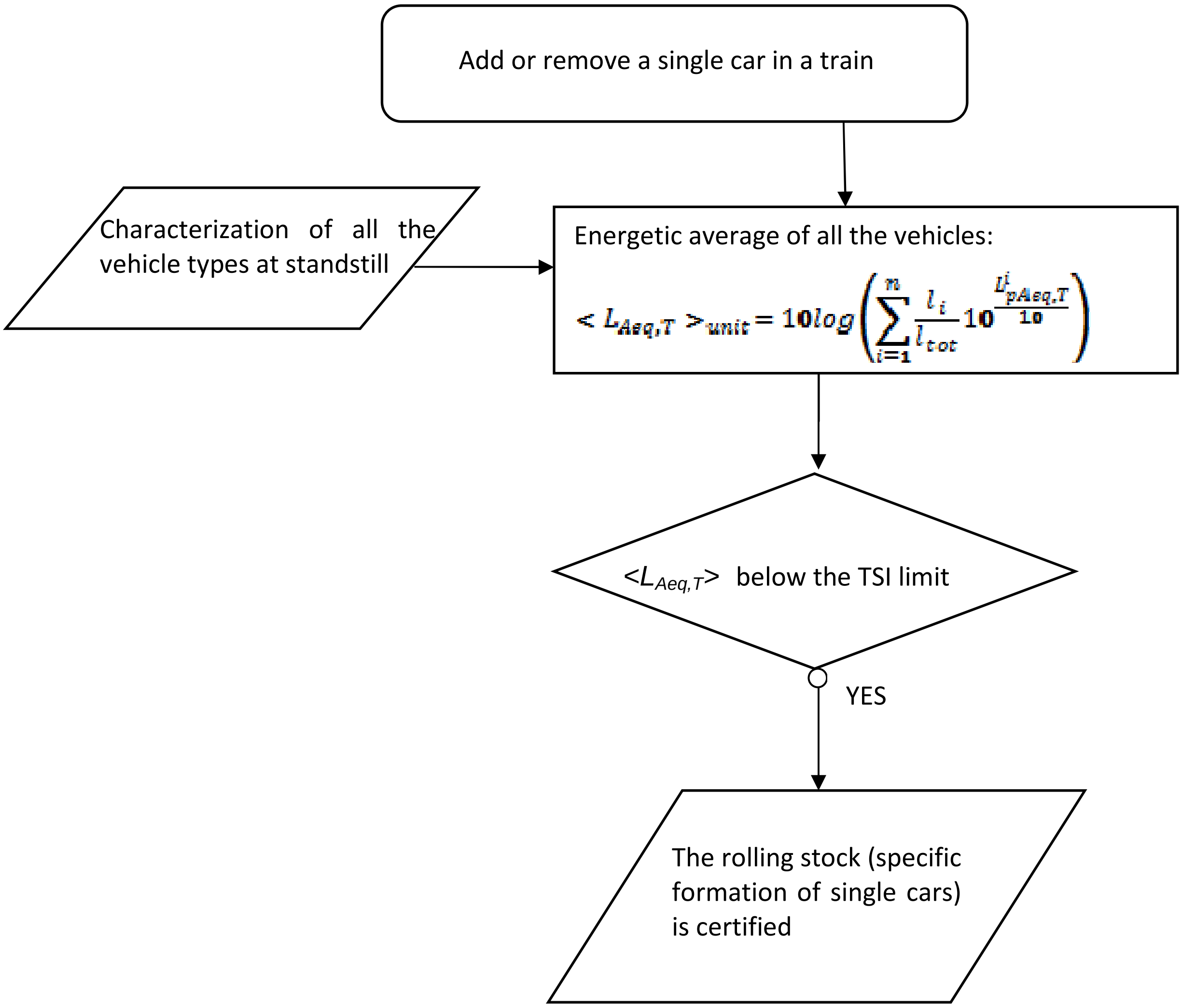
The process described in the flowchart above does not take into account the assumption that rolling noise dominates the global pass-by noise. Therefore the comparison is directly made on roughness spectra.

3.5 TRAIN WITH DIFFERENT SINGLE CARS FORMATION STATIONARY CASE

For: EMU/DMU

All the vehicles of the train should be acoustically characterized (2).

The new stationary noise can be computed with an energetic summation of the different units forming the vehicle.



Where l_i is the length of the i^{th} vehicle and l_{tot} the length of the train.

(2) Acoustically characterized: list and compare the main noise sources of the different vehicles:

- Check the sound power level of the different sources measured in lab

Why is this flowchart valid? How to interpret it?

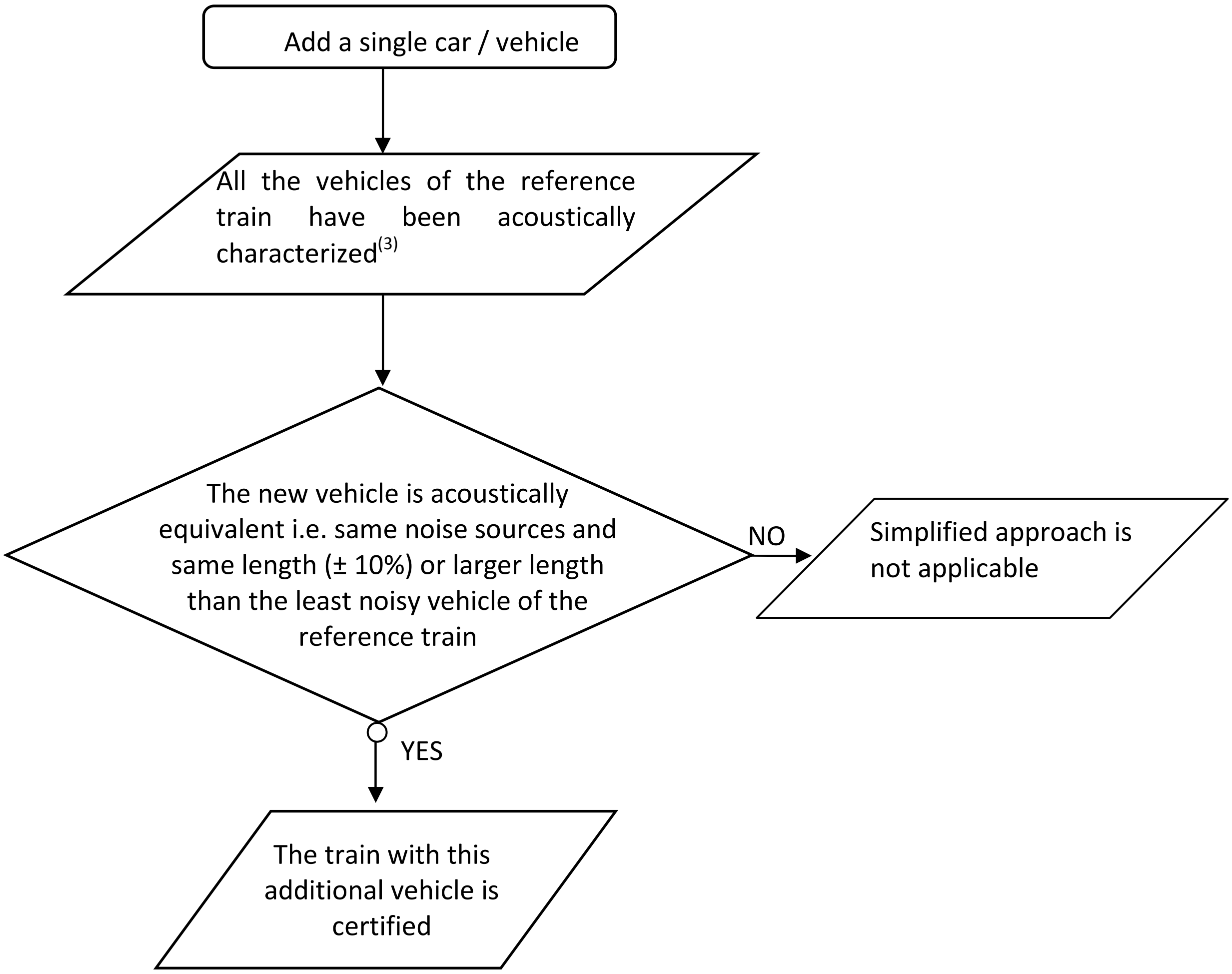
As mentioned in *Létourneaux & al. [2]* in the current TSI Noise (2011) there is actually a description of a simplified method for different formation at stationary noise. BT has used this method twice. In the first case a 4 car EMU was tested. The trainset was acoustically symmetric, meaning that the car formation can be described as A+B+B+A. The complete train was in fact measured but the wheather conditions were bad enough for the second half to make these data unusable. The TSI Noise then allowed duplicating the good measurements of the A and B car into the evaluation formula. In a second application BT again could re-use the good measurements of the A and B car types. In this case there was a different formation of type A+B+A and the measurement data of the cars were fed into the evaluation formula in the TSI Noise.

3.6 Addition of a single car / vehicle – Pass-by noise

For: EMU/DMU

All the vehicles of the reference train should be acoustically characterized [3].

To add a vehicle, one should compare the new vehicle with each of the vehicles in the reference train formation. If the acoustic sources of the new vehicle are the same as the ones of the vehicle with the lowest contribution to total noise and the length is the same or larger, we could accept adding this new vehicle.



(2) Acoustically characterized: list and compare the main noise sources of the different vehicles:

Rolling noise sound power level checked with TWINS calculation

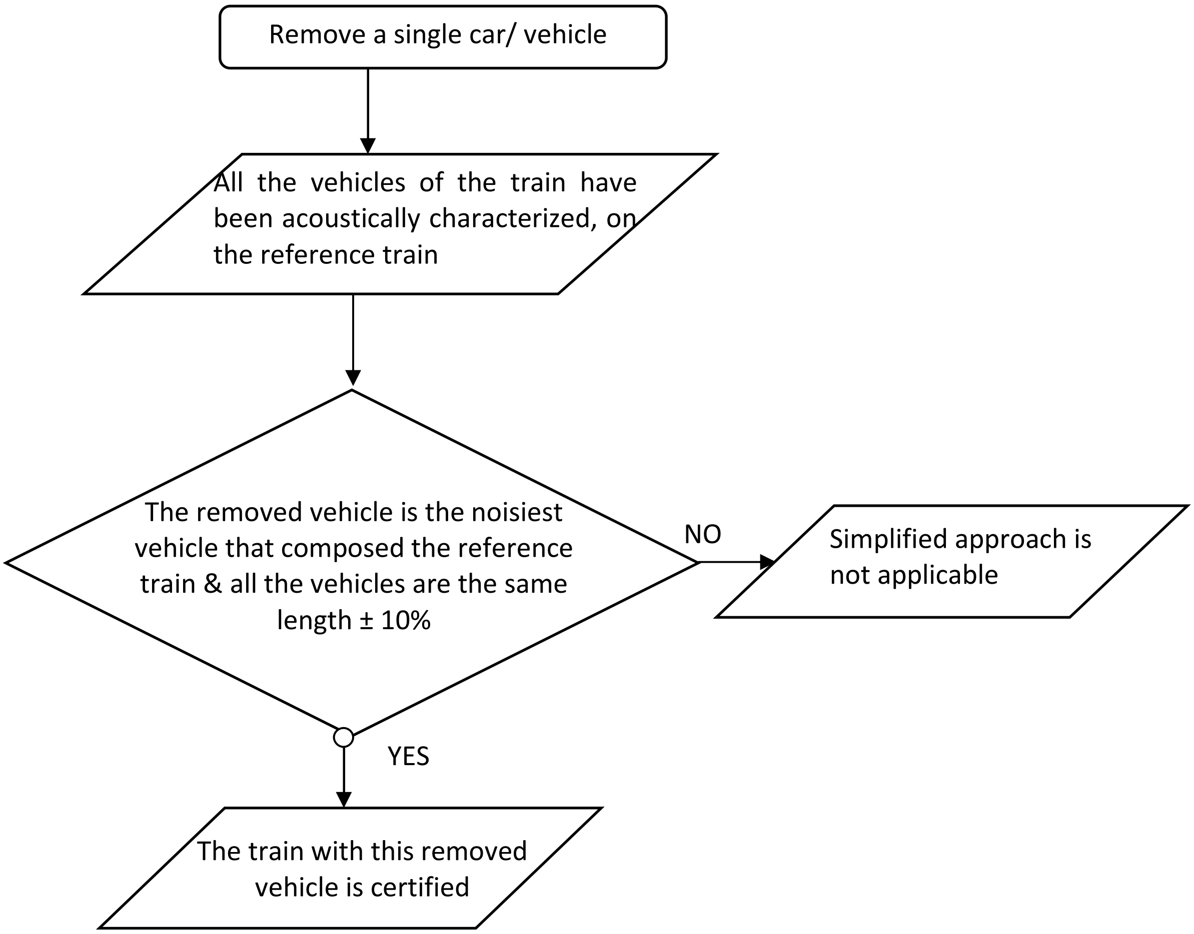
Check the sound power level of the different sources measured in lab

3.7 REMOVAL OF A SINGLE CAR – PASS-BY NOISE

For: EMU/DMU

All the vehicles of the train should be acoustically characterized.

Only the noisiest vehicle can be removed (considering that the lengths of the single cars are equivalent all together).



Why is this flowchart valid? How to interpret it?

This procedure has already been experienced by BT:

BT recently used the simplified method for the certification of a 4 cars EMU, based on a 3 cars EMU of the same family, already certified.

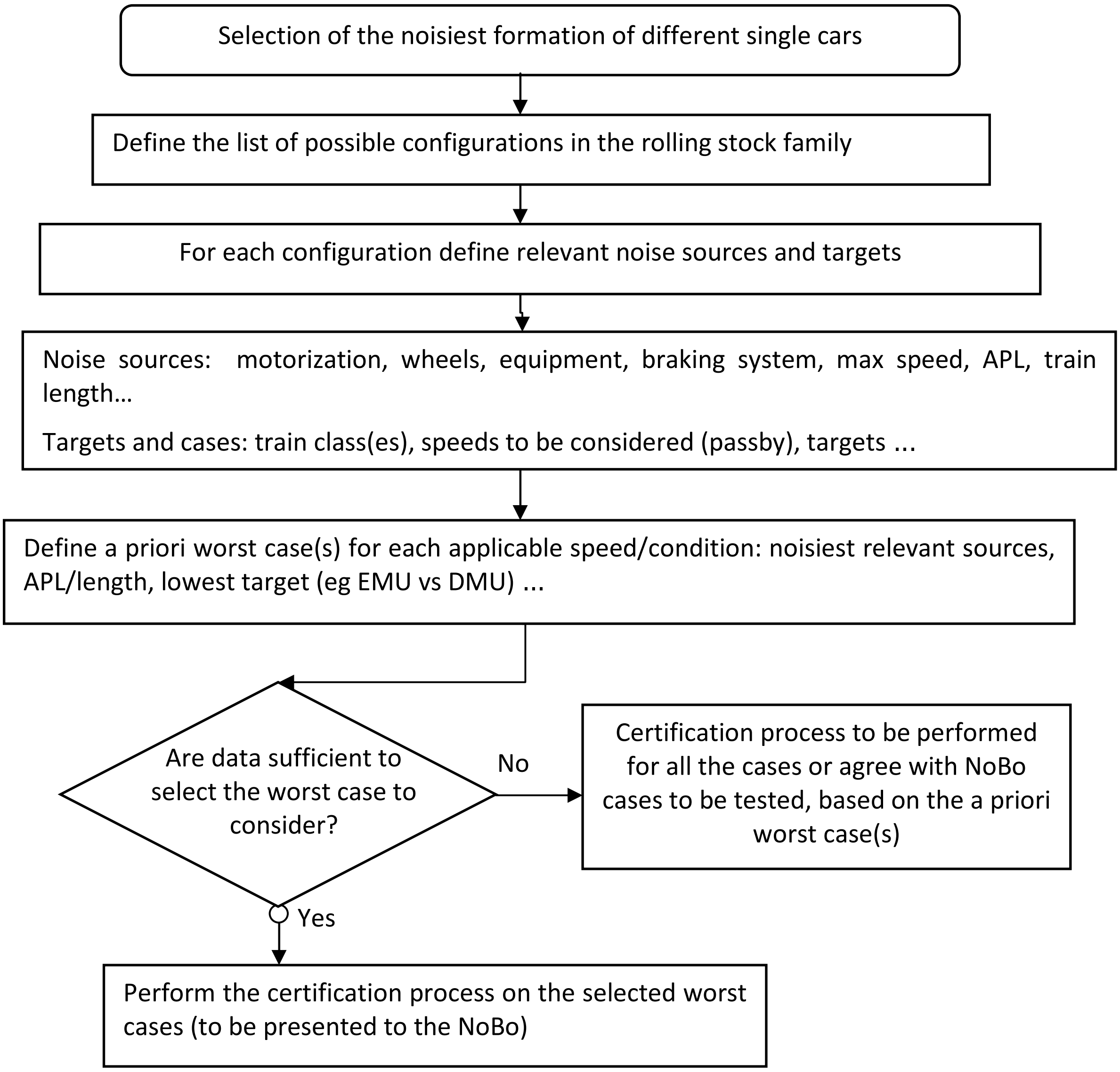
Measurements of each unit at standstill were carried out. Then BT used the numerical tool BRAINS © to combine the different units. The 3 cars EMU model in BRAINS was validated with existing certification measurements and re-used for the 4 cars EMU.

The NoBo accepted the calculations coming from BRAINS.

3.8 SELECTION OF THE NOISIEST FORMATION OF DIFFERENT SINGLE CARS – STATIONARY / PASS-BY / STARTING

For: EMU/DMU

The certification measurement campaign will only be carried out for the noisiest formation. The noisiest formation can be selected from a functional analysis of the different formations.



Why is this flowchart valid? How to interpret it?

This procedure has already been experienced by ATSA for the certification of one of their EMU/DMU new rolling stock:

A list of all the possible configurations of a RS was presented to the NoBo. For each of these configurations, targets and working modes were defined as well as the characteristics that can have an impact on the noise sources (for example: motorization (power_pack or pantograph), equipment working mode (transformer)) or on the targets and cases (for example: train classes – DMU or EMU -, speed to be considered: 80 and 160km/h)

A priori worst cases were selected. It corresponded to a configuration where powerpack is mounted on a train, with a 25kV transformer (it had been shown with lab test measurements that the noise with a 25kV transformer is higher than for the case with 1.5kV transformer). Equivalent configurations were discarded (arrangement of interiors). Finally, two a priori worst cases were retained: a worst case for the DMU configuration and a worst case for EMU configuration.

Calculations were performed with the numerical tool Sitare in the two cases for all the running configurations: acceleration, pass-by at 80km/h, pass-by at 160km/h, standstill and cabin noise. The results of the calculations showed that the 2 configurations, EMU or DMU, were similar: it was not possible to choose which one was the noisiest one so both were tested. In accordance with the NoBo, it was decided to carry out the homologation in-situ testing only for the identified EMU worst case and DMU worst case.

3.9 MODIFICATION OF EQUIPMENT OR ITS INSTALLATION – STATIONARY / PASS-BY / STARTING

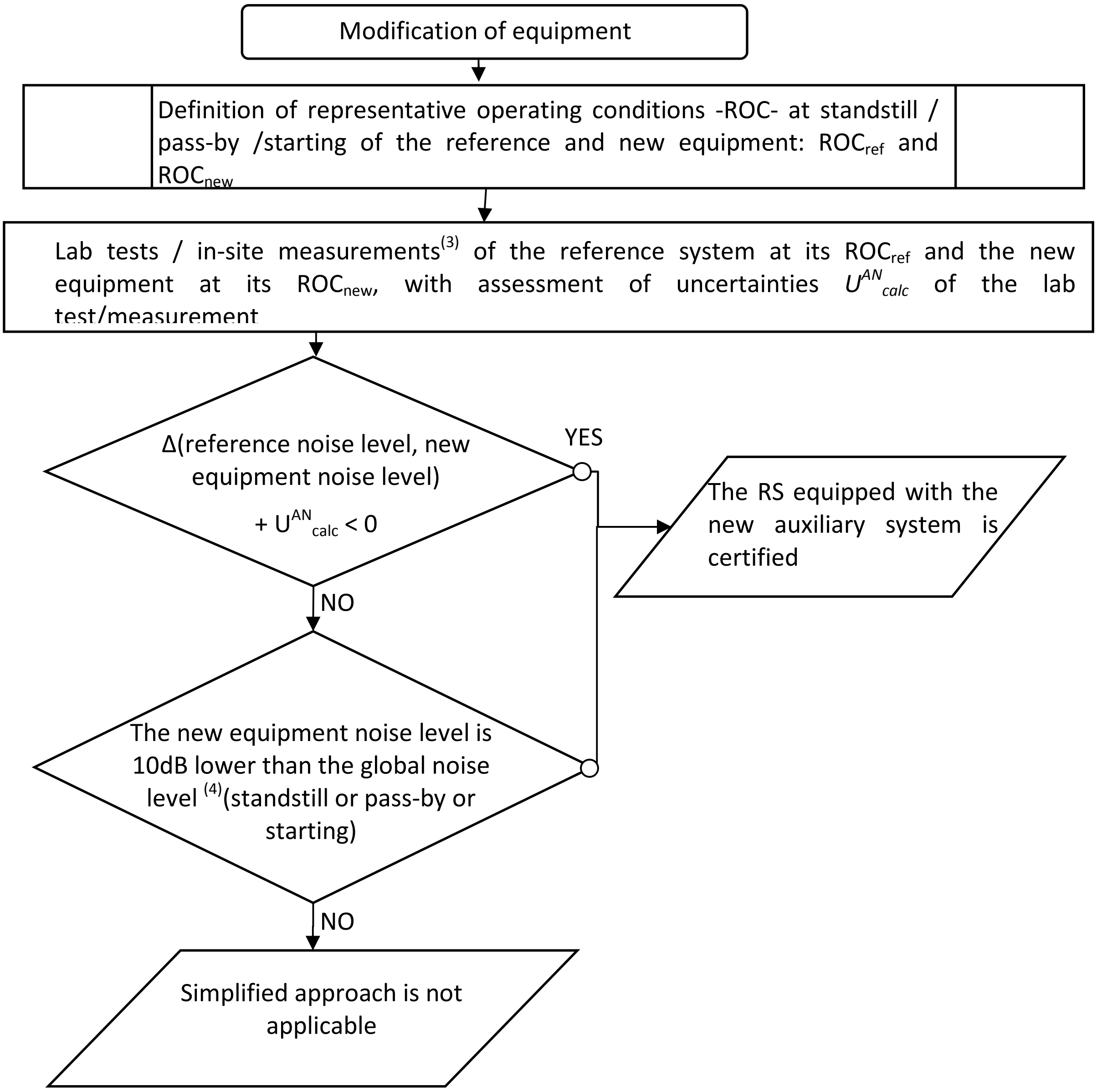
For: EMU/DMU – locomotive – high speed train – Freight wagon

Equipment refers to traction equipment and auxiliary system

The reference equipment corresponds to the equipment on a reference vehicle, i.e. a vehicle already certified.

The following diagram gives the methodology to check that the modification of specific equipment implies no effect (no change in the noise level) or a positive effect (decrease of the noise level) on the stationary, pass-by or starting noise so that the train equipped with the new equipment is automatically certified.

Concerning the installation effect, no dedicated standard exists to assess it. The sound power measurement standards such as ISO 3744 or ISO 9614 could be used with/without encapsulation, making sure that directivity of the measured sources is in the same time assessed.



Remark: Removing a source without changing the ROC of the other sources should be always allowed

(3) Needs of documentation about the evaluation of the equipment noise level – measurement methodologies (see the recommendations proposed in the ACOUTRAIN WP3)

(4) 10dB lower implies a max deviation of 0.5dB on the global noise

Why is this flowchart valid? How to interpret it?

Version of this procedure has already been experienced by ATSA:

1) In case of a modification of the auxiliary converter of a regional EMU:

a difference analysis was performed to demonstrate that the operating conditions are the same in both cases (the reference and the new one).

Then, lab of the reference system at its ROC_{ref} were carried out, tests based on ISO3744 with a dedicated post-processing, without any uncertainty assessment. The measurement showed that the dominating noise of the equipment is due to the cooling system.

Difference analysis: the changes do not affect the cooling system

The RS equipped with the new auxiliary system has been certified in all conditions

2) In case of a re-homologation (this case corresponds to two modifications of equipment):

A train A had been homologated versus the TSI HS 2002. It is currently running in a number of different countries in Europe. Another train B was being built on the basis of train A, to run in a country different than the ones that train A had been certified for. The NSA of that country accepted to give track access if train B proves to be TSI HS compliant.

To do so, ATSA has defined a list of gaps between train A and train B and sends an analysis to the NoBo. On noise, there were 2 differences:

- Change of the air production unit/compressor
- Removal of one component (sound source)

After preliminary discussions, the NoBo reviewed the list of differences presented above and requested a detailed documentation of each difference. Drawings of the two compressors were sent to the NoBo. Finally, the compressor was considered as not relevant for the assessment of noise emission according to the TSI-noise because it is an intermittent source (so it is not taken into account in the pass-by noise). From the operating conditions point of view, the working point of any other system was proven to be unchanged.

The final assessment of the NoBo about the train B noise was that:

- The change of the compressor does not affect TSI HS 2002 targets
- The removal of the equipment has no impact (or positive impact) on the global noise (its removal does not impact any other noisy equipment)

At the end, the NoBo concluded that the acoustic part of TSI HS 2002 was accepted for the train B on the basis of train A results.

4. REFERENCES

[1] Commission 2006/66/EC: Commission decision of 23 December 2005 concerning the technical

specification for interoperability relating to the subsystem 'rolling stock— noise' of the trans-European

conventional rail system. Official Journal of the European Union L37 (Volume 49), p 1-49

[2] Létourneaux, Meunier & Fodiman & *From limited to a full revision of the Noise TSI: Presentation of simplified evaluation methods for the verification of conformity*, 9th WCRR Lille 2011

[3] NB-Rail, RFU-RST-027, *Recommendation for Use - Assessment of conformity concerning noise,* Issue 01 13.02.2008

[4] EN13979-1 (2004) Railway applications - Wheelsets and bogies - Monobloc wheels - Technical approval procedure - Part 1: Forged and rolled wheels;

[5] ISO 9614-1:1993: Acoustics -- Determination of sound power levels of noise sources using sound intensity

[6] EN ISO 3095: 2005 Railway Applications – Acoustics – Measurement of noise emitted by railbound vehicles, 2005