Edinburgh, Scotland
EURONOISE 2009
October 26-28

Advancement in the development of European common noise assessment methods: where are we?

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ABSTRACT

In the context of the European Environmental Noise Directive (2002/49/EC)[1], to improve the quality and reliability of the overall noise assessment results, the European Commission intends to prepare common noise assessment method for road traffic, railway traffic, aircraft and industrial noise, including guidelines on method implementation and input data, aimed at obtaining comparable results across the EU Member States.

A roadmap for preparing the common noise assessment methods was established by DG ENV of the European Commission. This includes the identification and evaluation of existing methods on the basis of the following criteria: (a) ability to consider differences in noise source amongst EU regions (specific features which vary due to environmental factors like road and railway surface maintenance, specific regulations in force, techniques used to prevent noise, road & railway networks and aircrafts fleets); (b) ability to consider meteorological effects; easiness of implementation; (c) availability free of intellectual property rights; (d) integration of scientific evidence; (e) availability and quality of input data; (f) fulfilment of the requirements of the END.

In the period December 2008 to August 2009, DG JRC in co-operation with the European Environment Agency elaborated requirements on the input values and their associated quality in view of the next round of European noise mapping and identified and scrutinised the noise assessment methods that best cover the needs and requirements of the END with regard to strategic noise mapping. These preselected methods were proposed to DG ENV for further consideration for establishing the common noise assessment methods in EU. In a second step, those parts of the selected methods that fulfil at best the criteria of the evaluation will be used to produce a 'fit for purpose' framework for common European noise assessment method(s).

1. INTRODUCTION

The European Environmental Noise Directive (2002/49/EC) requires to the Member States to produce noise maps and noise reduction action plans and also aims at rising awareness about

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environmental noise exposure at both European and national levels. According to this Directive, these noise maps and action plans should have been obtained by employing either the interim noise assessment methods or equivalent national methods and using recent input data on the specific noise sources, surrounding environments and population distribution in buildings.

During the period 2002-2007, the EU MS prepared noise maps of the major transport infrastructures (i.e., roads with more than six million vehicle passages a year, railways with more than 60.000 train passages per year, airports with more than 50.000 movements per year) and sites with industrial activities and within the major agglomerations exceeding 250.000 inhabitants. In the year 2012 a new round of noise mapping will include transport infrastructures with even lower traffic (roads with more than three million vehicle passages a year and railways with more than 30.000 train passages per year) within agglomerations of more than 100.000 inhabitants.

The European Commission provided the Member States with recommendations and guidelines on the use of the assessment techniques and for clarifying unclear provisions of the Directive (i.e., Commission Guidelines adopted on 6 August 2003 and WG-AEN "*Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure*")[2]. Also, the European Environment Agency provided support to the collection and delivering of the noise maps through the Environmental Noise Directive Reporting Mechanism (ENDRM)[3] including the Reportnet IT tool[4].

Regardless of the aforementioned supporting documents, the production of noise maps by the EU MS followed different approaches between and within the different Member States that consequently influenced the quality of the noise maps.

The first round of noise mapping produced a picture of the noise exposure in Europe difficult to compare, partly because of differences in the noise sources amongst EU and in the policies adopted by the MS to reduce harmful noise levels, and partly due to different approaches used by the MS in the calculation and reporting of the information relative to noise mapping and population exposure.

For the time being, many EU Member States opted for using their own national methods, even if it can be anticipated that the various noise mapping methods actually used in Europe would produce different results. These results might differ by orders of magnitude and therefore it became obvious that there is a need to proceed with harmonising the approaches actually used for noise mapping calculations. This will be achieved by elaborating, adopting and finally enforcing robust and high quality common noise assessment methods.

In article 6 of the Directive it is stated that: "*common assessment methods for the determination of L_{den} and L_{night} shall be established by the Commission in accordance with the procedure laid down in Article 13(2) [regulatory committee] through a revision of Annex II*".

During the noise regulatory committee meeting that took place on the 7th of May 2008 in Bruxelles, DG ENV informed the Member States that the Commission for ensuring consistency of noise exposure data across the EU intends to come up with common assessment methods for environmental noise mapping in the context of the review of the Environmental Noise Directive. MS anticipated their willingness to support this initiative of the European Commission. Harmonisation of the approaches is required to achieve accuracy, precision and credibility of the assessment performed throughout the EU. This is also a condition "*sine qua non*" estimation of population exposure at EU level cannot be achieved with acceptable accuracy.

In the last meeting of the EC Working Group on "Assessment of Exposure to Noise" (WG-AEN) that took place on the 9th of September 2007 in Ispra, the members of this WG also supported the aforementioned initiative of DG ENV.

Several of the existing methods may a priori be considered as possible candidates in the context of the harmonisation process. However, it is currently difficult to compare the possible candidate methods in a straightforward way. This, is due to the fact that available noise assessment methods have been validated under specific conditions, which in general reflect the particular situations encountered in those countries where the methods were developed. Rarely, these methods have been validated under different situations, representative of all possible EU conditions and especially in urban areas.

There is therefore a need to carry out a sound evaluation of the existing methods on the basis of appropriately chosen criteria that shall provide a good understanding of the capabilities, strengths and weaknesses of the candidate methods.

The DG Joint Research Centre (JRC) of the European Commission, in the context of its technical support to the Directorate General for the Environment (DG ENV) related to the implementation of the European Noise Directive 2002/49/EC (END) is working on the preparation of common noise calculation methods to be proposed in the context of the revision of this Directive.

In the period December 2008 to August 2009, the noise assessment methods that best cover the needs and requirements of the END with regard to strategic noise mapping were identified, scrutinised and finally proposed to DG ENV for further consideration for establishing the common noise assessment methods in EU.

During the aforementioned period, the following sub-tasks were performed by DG JRC in co-operation with the European Environment Agency and with the involvement and contribution of noise experts from the EU Member States:

1. A workshop on "*The target quality and input values requirements for European noise mapping*" was organised on 17-18 March 2009 in Ispra[5] in cooperation with DG ENV and the European Environment Agency;
2. A literature survey on existing noise mapping methods available in Europe, USA and Japan was done to serve as the basis for performing a sound evaluation and selection of the most appropriate methods to be further scrutinised in the context of the development of the European common noise calculation methods.
3. Requirements and criteria to be applied for the selection of the future common noise assessment methods were elaborated and finally established.
4. On the basis of the aforementioned requirements and criteria existing noise assessment methods previously identified through sub-task 2 were scrutinised and evaluated on the basis of requirements and criteria established under sub-task 3 and finally a subset of them were proposed to be further considered for establishing the common noise assessment methods in Europe. In a second step, those parts of the selected methods that fulfil at best the criteria of the evaluation will be used to produce a '*fit for purpose*' framework for common European noise assessment methods.

2. NOISE MAPPING: TARGET QUALITY AND INPUT VALUES REQUIREMENTS

In the context of the last Noise Regulatory Committee meeting in May 2008 and during other recent technical and scientific forums, representatives and experts of the EU Member States expressed their concerns about the quality, availability and comparability of input values and techniques used in the noise mapping.

Inconsistencies in noise maps across member states will arise despite them using the same interim method (and/or equivalent to interim methods) and even if a common method will be in place in the future – due to the quality of the input data.

In this perspective, before proceeding to the selection of potential common assessment methods, a key issue to be tackled is the quality of the results that would meet the general objectives of the Directive. The quality of the results can be reasonably achieved provided that the following issues will be considered and properly managed: availability of the required input values to public environmental offices and private consultants, quality of these data, guidance on the use of calculation methods and their implementation into calculation software and format of the data to be exchanged.

The EC is expected to consider these issues in its proposal for common European methods. Feedbacks received from National authorities and consultants directly involved in the preparation of the noise maps during the first round of noise mapping is considered an essential prerequisite to understand where to put emphasis in the preparation of common methods. In this perspective, DG JRC in cooperation with DG ENV and the European Environment Agency organised on 17-18 March 2009 in Ispra the Workshop on "*Noise mapping according to the 2002/49/EC: TARGET QUALITY AND INPUT VALUES REQUIREMENTS*".

The common noise assessment methods are expected to include guidelines on the collection of input values and on their associated quality and this workshop constituted a first step towards achieving this.

This workshop addressed the EU MS noise representatives, public authorities, private noise consultants and software developers already involved in the 1st round of European noise mapping who were invited to contribute to the development of requirements on the input values and their associated quality in view of the next round of European noise mapping.

The importance the aforementioned event received among the various stakeholders was reflected in the broad participation that included almost 80 people from 20 European Countries representing: European Commission and Agencies (7), National / Local Authorities (32),Software Developers (3), Research Institutions / Universities (15), Private Noise Consultants (21), Industry (1). The European Commission services participated were DG ENV, DG ENTR and DG JRC and the three agencies were the European Environment Agency (EEA), the European Railway Agency (ERA) and the European Aviation Safety Agency (EASA).

At first the workshop's participants were introduced to some key elements of the process of noise mapping, and their effects on the final results, both in terms of calculated noise levels on the noise maps produced and also in terms of estimation of population exposure, namely: the process of selection of the quality of the input data used; the choice of a specific set of parameters in the calculations; the assumptions made in attribution of the noise levels to population exposure; the calculation methods used; the method used to collect and report data to the EU and finally the interpretation of unclear or missing provisions of the END.

Technical presentations by invited experts then followed focused on: (a) the requirements on the quality of the final results; (b) the relevant (but difficult to retrieve) input values for noise mapping; (c) the critical input parameters for road, railway, industrial and aircraft noise assessment; (d) the potential relationships and relevance to the "Noise Community" of the INSPIRE Directive Data Specifications ; (e) the necessary quality of the input data in the noise mapping methods as a function of expected output results and (g) how decisions taken at each implementation stage can influence the outputs required by END.

The Workshop was then mainly developed through a plenary session in which an open discussion was triggered by a list of questions on general issues addressed to the participants These questions were prepared by DG JRC and fine-tuned before the workshop with the assistance of the newly formed EpoN working group (Experts' panel on Noise, managed by EEA). The aim was to discuss and to seek consensus about issues relevant for ensuring acceptable and measurable level of quality of the noise mapping process. The questions/issues addressed to the participants were:

1. From your practical experience what was the most difficult input data to obtain for noise mapping?
2. What is your view on using perhaps a less accurate method than your own National method if this may be required for achieving comparable results at EU level?
3. Which is your opinion about using a computation method to model quiet areas in which there maybe a lack of input data for modelling purposes?
4. Do you agree that for obtaining reliable and comparable results at EU level we should proceed with establishing common assessment methods?
5. Do you agree that to maximise the reliability and comparability of results a guidance on the competent use of noise assessment methods accompanied by a quality system should be established in relation to: software calculation settings; software use and modelling; how to use, extract, extrapolate and manage input data; the relevant quality and quantity of input data;
6. As part of a quality system to be introduced which is your opinion about the following elements to be considered?

- Specifications for GIS input/output data and data collection
- Specification on degree of accuracy tailored for different noise mapping needs (e.g., strategic - global- noise mapping versus local detailed noise mapping)
- Reporting scheme
- Population attribution
- Software input/output screen/mask to be normalised to ensure transparent and reliable use of assessment methods
- Specified conditions related to the definition and usage of "default" input data
- An EU calculation open source and validated code (for both strategic and detailed noise mapping) which will be updated centrally by EC
- The constitution of an open and public database of input values, that is centrally managed and periodically updated by the EC on the basis of contributions from the EU MS

7. Should we ensure the same degree of "comparable" results for all four calculation methods (i.e., road, railway, industrial and aircraft) or should we treat noise sources differently "between" and "within" them in terms of accuracy and number of people affected?

8. How effectively could the integration of the noise GIS data into the set-ups under the INSPIRE directive (Annex 3) be achieved?

9. Have you explored the possibilities of synergies among the END and activities under other Directives (e.g., the Air Quality Directive)?

Then the participants were splitted into two breakout working groups, the first dealing with specific input values required in the noise mapping of road and railway and the second on those required by aircraft and industrial noise. Discussions in both working groups dealt with the following issues:

- The set of parameters/input values used in the four noise sources.
- The accuracy (of the single point calculated level if this specific parameter is uncertain).
- The easiness to find/retrieve/use a specific parameter.
- The problems encountered during the first round of noise mapping and/or the lessons learned concerning the use of a specific parameter.
- The inclusion of a parameter as mandatory to be used or its exclusion from the mandatory set because it is considered negligible or inappropriate.
- The existence of standards to use/acquire this parameter or the need of standardisation if no standard exists.
- How the parameter matches the INSPIRE definitions.
- The possibility to evaluate type 'A' uncertainty for this input parameter.

The overall conclusions from the breakout session on *road and railway traffic noise* may be summarised such that any proposed common assessment method:

- Should be of high enough quality to support good assessments where possible;
- Be fit for the purpose of supporting policy developments, either in local action plans or at EC level;
- Should accept use of default or toolkit approaches;
    - Provided impact of data shortages are estimated and catalogued through the use of uncertainty statements
- Would require support and guidance; and
- Should provide an assessment of noise which is credible to the end users, including the public, authorities and mapping bodies.

It was also concluded that:

- Validation through measurements play an important role;
- Data input quality specifications are reliant upon the specific method of assessment; and
- Clear and detailed guidelines and recommendations are necessary for several specific issues.

As far as the aircraft noise is concerned, the majority of the participants believed that the most realistic way forward for aircraft noise modelling in the second round of END is by means of an integrated method like ECAC Doc 29 3rd Ed. In any case, whatever model will be finally used:

- It should allow for several levels of details of input data subject to availability
- It should have a single noise & performance databases for all MS

Clear and detailed guidelines and recommendations are necessary for several specific issues.

Based on the discussions held during the Workshop, general conclusions and recommendations for future actions were drafted for which consensus of the Workshop's participants was achieved. These were mainly concerned with some fundamental improvements that were retained as necessary to be included in the second round of noise mapping to ensure ***"precision, accuracy and credibility"*** of the noise maps and of the population exposure estimations. These are briefly summarised below:

- ***Reliable and comparable results*** at EU level should be obtained through establishing common assessment methods.

- The reliability and comparability of results should be maximised through setting up a ***guidance on the competent use of noise assessment methods*** accompanied by a ***quality system*** in relation to:

    a) the relevant quality and quantity of input data;
    b) the use, extraction, and management of input databases;
    c) the calculation settings in software;
    d) the software use and the modelling techniques used.

- ***Reporting mechanism*** to report noise maps and population exposure should be made mandatory.

- The quality system to introduce regarding input data collection and use should specifically comprise the following elements:

    - Specifications for ***GIS input/output*** data and data collection
    - Specification on ***degree of detail*** of the input data tailored for different noise mapping needs, e.g., strategic (global) noise mapping versus detailed (local) noise mapping for action planning
    - A standard scheme to be followed for the ***collection*** of information on the datasets used and ***data processing*** procedures used
    - Specific conditions related to the definition and usage of "***default***" input data
    - A fixed methodology to ***attribute population exposure*** to noise levels

- An ***EU calculation code*** (both, for strategic and detailed noise mapping) should be established and updated centrally and periodically by the EC in collaboration with the software developers.

- There is a need to constitute an ***open and public database*** of global input values to be used together with the common assessment methods, that is centrally ***managed and*** periodically ***updated by the EC*** on the basis of contributions from the EU MS

- The same degree of ***"comparable" results for all four calculation methods*** (i.e., road, railway, industrial and aircraft) should be ensured.

- An integration of the noise GIS data into the set-ups under the ***INSPIRE*** directive (Annexes I to III) is envisaged.

In the absence of a proposal for a "common methodology" it was also quickly agreed that specific recommendations on the quality of input datasets, the use of specific existing WG-AEN GPG toolkits, or the requirements for extending this concept, would not be possible as the required input data quality is determined by a combination of the desired target accuracy, which is largely determined by the purpose or policy, along with the method of assessment being used. As neither aspect was defined, the specific input data quality indicators could not be estimated at this stage.

Furthermore, there may be different requirements on a modern noise assessment method, depending upon the purpose of the assessment. Two main purposes were identified and agreed upon in the Workshop and further elaborated in the next step of the roadmap to prepare common noise assessment methods in the EU.

A **first purpose** relates to the ability to perform an overall impact assessment of sound exposure in large urban areas, and through a common approach to identify hot spots and quantify overall numbers of people exposed and associated health effects, with reasonable approximations. In this case, there is no need to seek for highly accurate results for each specific assessment position and a reasonably simplified assessment approach might be sufficient (i.e, the same method is used with simplified set of input values). This is mainly needed for fulfilling the obligations of **strategic noise mapping required by the END**. The use of the common noise assessment methods for this first purpose includes:

1. Support to the EU level policy:
    a) Strategic noise mapping results need to provide an overall health impact assessment across the majority of the population thought to be exposed to environmental noise as this is considered to pose a potential long-term risk to health and well-being.

A **second purpose** relates to the precise determination of the noise levels to which people are exposed, eventually within those areas where deeper understanding of the problem is required to identify, implement and evaluate the effectiveness of action plans either at local level, at MS level or at EU level. Detailed results can be obtained by appropriately employing the common assessment methods with detailed input values. Examples of possible use of the assessment methods for this second purpose are:

1. Support to the EU level policy:
    a) Noise mapping results need to provide supporting information to provide a basis for source noise legislation (including tyre noise, vehicle pass by noise, road surfaces descriptions, rail vehicle interoperability, aircraft fleet restrictions etc).
    b) The method needs to be able to support these policy areas by being able to use such data as inputs, either to reflect the current situation, or to run "what if" scenarios to help formulate policy alternatives and assess their impact. This will enable the EU MS to undertake an assessment of the impact of policy alternatives, thus formulate appropriate proposals to the European Council.

2. Support MS level policy aspects:
    a) vehicle restrictions
    b) tyre restrictions or special types
    c) traffic calming
    d) promotion of electric / hybrid vehicles
    e) promotion of vehicle fleet change through financial incentives to scrap older cars, older trains, older aircrafts
    f) noise-differentiated track and airport access charging
    g) action plan policies etc

3. Local Action Plan policy aspects:
    a) local actions such as those within the ‘Silence’ handbook
    b) road surface changes
    c) different types of barriers (in general, e.g. berms, walls, embankments etc.), their materials, shapes, sizes, acoustical performance or other functionalities

(e.g.: absorbent/reflective, curved, tilted, complex overhanging, with photovoltaic devices and with top devices).

d) rail grinding, rail vehicle brake changes, tuned rail absorbers, mitigation of rail curve squeal
e) transferring night time rail and aircraft movements to the day
f) switch to different type of cars and trains (e.g.: electric/hybrid cars, diesel to electric locomotives)
g) low emission zones
j) calculations for quiet areas in open countryside

The method should reflect - as much as possible - the effects of all such action plans in future strategic noise maps. Not showing the effect of some action plans might discourage the MS to undertake such actions and/or to prefer "well known" types of actions (taken into account by the prediction methods) compared to more innovative actions (whose effects are not well taken into account by the prediction methods).

For both purposes, it should be possible to use the common noise assessment method with reasonable effort. Consequently, requirements on input data might be kept commensurate with the level of resolution and accuracy relevant to each purpose of the assessment. These needs are best described by a "**fit for purpose**" approach, and this approach should be kept in mind in the preparation of the common noise assessment methods.

It was acknowledged that many of the existing national methods do not provide support for many of the above aspects, and thus would not actively support the assessment of policy options or action plan cost benefit analysis. It was considered that the applicability of the common noise assessment method to use in action planning and policy development was probably a key aspect going forward, and is probably an emerging requirement compared to traditionally-designed national methods which may have been designed primarily for use in Environmental Impact Assessments, or testing against limit values.

For the detailed reporting on the outcome of the Workshop's plenary and break-out sessions the reader is advised to consult the following web address: http://ec.europa.eu/environment/noise/.

3. LITERATURE SURVEY ON EXISTING NOISE MAPPING METHODS IN EU, USA AND JAPAN

Existing noise mapping methods typically aim at calculating noise levels produced by specific noise sources, at defined single assessment positions. Traditionally, they were developed based mostly on theoretical assumptions, implemented through mathematical formulas and with coefficients obtained by means of noise measurements in simple situations and subsequent statistical analyses of the values recorded. Verification and correction of the methods was performed on the basis of comparisons against real situations. Many of the noise mapping calculation methods have features in common such as the set of elements considered in the noise modelling, and the corrections they include. For example, the effect of speed of vehicles on noise levels in the case of the source description, and inclusion of ground absorption in the case of the propagation, etc. This does not necessarily imply that these various elements among different methods are described by the same mathematical expression.

For each method, there are specific classes of source and propagation elements defined. The situations for which the source and the propagation are described, the obstacles and the

receiver configurations included in the method description can vary between methods depending on the peculiar situation for which a method was developed.

In a noise mapping calculation method, most often simplified configurations are presented and clearly described, while it is let to the final user to interpret how to perform calculations in more complex situations or in others not described in the documentation accompanying the method. Because of the physical complexity and variability of noise, and because of the difficulty to model all physical effects precisely, some of the existing noise mapping calculation methods state the limits of their applicability and declare that verification is required in specific cases.

In several cases, the methods are updated after some years, or amended to consider new needs in the calculations or in the recently developed noise indicators (e.g.: some methods have undergone an adaptation to be capable of calculating L_{den} and L_{night} levels after the introduction of the Environmental Noise Directive). Often, methods are the updated version of a previously existing self-standing method, and sometimes some of their parts were developed reflecting the corresponding parts of other methods. Thus, often happens that different methods do not necessarily consist of very different approaches related to the calculation of the noise levels, rather partially.

The methods developed in recent years, generally include a more sophisticated description of the source and propagation parts (e.g.: more line sources for the same environmental noise source, and propagation as a function of third octave bands). They tend to be oriented towards a clear separation of source and propagation parts as well as allow modification of the input parameters to analyse benefits obtained from specific noise reduction measures.

The publication of a noise mapping method once developed (or its subsequent updating) undergoes different paths. Existing methods can be in the form of national or international standards (e.g.: ISO, EN) or in the form of reference documents or even are simply a series of technical documents that have been prepared in the context of specific research projects.

In the context of this literature review, the aforementioned sources of information were considered along with the most quoted acoustic journals and conferences (e.g.: JASA, Journal of Sound & Vibration, ACTA ACUSTICA, Euronoise and Internoise Conferences) with the aim to scrutinise the existing methods on the basis of state-of-the-art technical/scientific knowledge.

It should be underlined that this literature review revealed that description of some methods (or part of them) are not publicly available because of intellectual property rights issues or because they are still in the publication phase. These methods were however included in the review because they are supposed to constitute the state-of-the-art in the field of noise assessment methods.

While in general enough documentation was collected that allows understanding and describes thoroughly all the methods considered, instead, it was not possible, in most cases, to get documentation related to the testing of the methods and the evaluation of their uncertainties and limits. This was a limiting factor for the evaluation of the methods because confidence in the application of modern noise assessment methods requires besides a transparent description of them, also verification and validation case studies.

4. REQUIREMENTS AND CRITERIA FOR THE SELECTION OF THE FUTURE EUROPEAN COMMON NOISE ASSESSEMENT METHODS

A. GENERAL REQUIREMENT FOR A "FIT FOR PURPOSE" METHOD

Based on the outcome of the aforementioned workshop and the rationale described in the last part of chapter 2, it can be deduced that the need for an appropriate noise assessment method in an EU context could be best fulfilled by a two level of input data method that can be used either ***using a simplified set of inputs, to fulfil the aforementioned "first purpose"***, or ***with a more detailed set of inputs to fulfil the "second purpose"***.

It should be noted that any detailed methodology can in principle ***be reduced to a simpler to use methodology*** by applying default values to most of its parameters and by performing calculations under a reduced number of source and propagation conditions. Also, methods using octave band data ***can be simplified to be used with A-weighted levels*** by means of the use of corresponding equivalent default spectra. Finally, a detailed method could allow fine-tuning of the input values and parameters to ***match the specific national source and propagation description of a pre-existing national method***.

On the basis of the aforementioned considerations, the ideal method would then be a complex method **which supports reduction to a simplified version, by fixing a set of input values (e.g. by using default values) and appropriate default assumptions** for those of the input values not commonly available. For example, the method, requiring octave band spectra, can be simplified to be used with dB-A weighted value by proposing source-specific default spectra to convert these dB-A weighted values to the required input data for the method.

B. SPECIFIC REQUIREMENTS FOR THE COMMON NOISE ASSESSMENT METHODS (FULFILL THE END AND TO BE APPLICABLE THROUGHOUT THE EU MEMBER STATES)

To fulfil the END requirements (Annex I in particular), the assessment method should be capable to:

- give $\mathbf{L_{den}}$ and $\mathbf{L_{night}}$ values;
- calculate each source type separately;
- give results at **4 m** height **0.1 m** in front of the façade;
- consider the **average meteorological year**;
- neglect the **effect of the façade reflection** of that façade corresponding to the assessment point;
- capable of calculating values for quiet areas

Moreover, given also the need to ensure not only calculations near to the source, but also far from it, it would be preferable to have:

- calculations in **octave bands** (Lots of data on sources is only available in whole octaves 63 to 8000 Hz**)**

Some more features are considered to be part of the set of standard requirements related to the common noise assessment methods:

- **geometrical** divergence**;**
- **atmospheric** absorption;

- terrain features (**height**, ground **impedance**);
- **reflections** and **diffractions** on and around obstacles (including buildings, screens and noise barriers).
- the **segmentation technique** (decomposition of large sources in smaller entities, based on acoustical criteria) should be specified for all sources;

To ensure an applicability of the methods in the different specific situations encountered in the EU MS, some more conditions should **possibly** be met, namely considering the following details:

For noise propagation:

- different **combinations of propagation conditions** are allowed;
- each propagation condition can be defined starting from **meteorological parameters** that influence the sound ray profile and air attenuation (temperature, humidity, air density gradients, wind speed and temperature gradients and wind direction).

For noise source definition:

ROAD TRAFFIC NOISE:

- at least four vehicle categories (motorbikes, passenger cars, light and heavy trucks);
- road surface types;
- differences in fleet composition between MS;
- different tyre types, engine noise/rolling noise;
- acceleration/deceleration, gradients;
- acoustical effect of specific points (tunnels, viaducts,…);
- effect of speed lower than 50 km/h.

RAILWAY TRAFFIC NOISE:

- different wheel and rail roughness;
- different track/support structure types and different vehicle types;
- different engine noise;
- different air management/cooling system noise;
- different aerodynamic noise;
- acoustical effect of specific points (squeal, bridges,…);
- easiness to obtain "national" emission date (i.e., to adjust the proposed default values based on measurements on specific rolling stock);

INDUSTRIAL NOISE:

- lateral diffraction around obstacles;
- specific modelling of low frequencies;

AIRCRAFT NOISE:

- different aircraft performance as a function of aircraft type, engine type and take-off weight (TOW);
- air parameters (temperature, pressure and wind speed and direction);
- different noise abatement procedures for both take off and approaches;

In addition, it is desirable to consider methods whose reliability is proven and whose uncertainties related to the results are known, therefore:

- **validity of the scientific background** of the parts that compose a method should be considered;
- **validation** of the results obtained by the application of the method complements the requirement on scientific background;
- **procedure to assess the uncertainty related to the method.**

For a method to be considered in the process of preparing common noise assessment methods, also it should be ensured that:

- the method is available **free of any royalties and IPR issues**;
- a clear description should accompany the methods; this will help an **easy implementation of the methods** into software and its usage by the end users;
- reasonable calculation times.

Concerning the easiness of use of the method, two more relevant requirements are considered:

- **availability** of the set of **parameters** and of the **input values**, at least default ones, to be used with the method;
- **frequency of update** of the parameters and the input values;
- **ability to adapt to local conditions (**such as different vehicle fleets, different railway tracks and road surfaces**).**

Preference will be given to solutions suggesting:

- **common parts between the road, the railway, the industrial and the aircraft noise calculation methods.**
- **clear separation of noise emission and noise propagation** (this will result in methods that are more easily adapted to new type of sources and/or in case of important technological changes at the source level).

These requirements are also based on the discussions held during the March 2009 workshop, where among the consensus reached on the various topics discussed, it was also suggested to have as much uniformity between the four methods as possible, given that the physics of noise generation and propagation remains the same regardless of the source, and comparable results is an asset.

C. CRITERIA FOR THE SELECTION OF THE FUTURE EUROPEAN COMMON NOISE ASSESSMENT METHODS

Many existing methods fulfil several of the aforementioned requirements, therefore it is expected that within the process of selection of the common methods a number of viable options may be identified. Some of the outlined requirements have been considered as '*essential*', meaning that the non-fulfilment of such requirement will result in considering such a method as inappropriate to meet END requirements and basic environmental noise assessment standards. The rest of the requirements not being essential are indicated as '*recommendable*' to be part of the common methods. This is to consider those requirements that are nowadays and in the next future welcome, mostly for properly evaluating noise reduction measures.

The procedure for the selection of the common methods consequently has been:

1) **to pre-select those methods that fulfil the essential criteria (mainly the requirements of the END);**

2) **to identify the best ones fulfilling most or all of the recommendable requirements;**

As an option was kept to combine parts of the existing methods provided that this is considered appropriate to obtain the 'best in class', conforming also to the necessity to develop a 'fit for purpose' method.

In the table 1, the requirements for the selection of the common noise assessment methods are summarized and ranked as '*essential*' or '*recommendable*' based on the rationale outlined above.

Table 1: *Requirements for the selection of common noise assessment methods in EU*

Requirements for the selection of the common noise assessment methods	**Essential**	**Recommendable**
GENERAL REQUIREMENTS		
Possibility to modulate the method between a detailed (user defined specific input values) and an easy implementation with default values	**X**	
Fulfilment of requirements of END (Lden and Lnight, 4m/0.1m, average meteorological year, neglecting corresponding façade reflection)	**X**	
Octave bands calculations		**X**
Geometrical divergence	**X**	
Atmospheric absorption	**X**	
Terrain profile	**X**	
Ground effect	**X**	
Reflections / diffractions	**X**	
Specific description of the segmentation technique to be used for decomposition of the large sources	**X**	
Propagation condition (are more propagation conditions allowed?)	**X**	
Meteorological influence (consider the effect of temperature, pressure, wind speed and direction on yearly average basis)	**X**	
ROAD SPECIFIC		
Road surface type correction	**X**	
Tyre type correction		**X**
Ability to split between tyre and engine noise		**X**
Acceleration/deceleration (Traffic flow)		**X**
At least 4 classes of vehicle types	**X**	
Gradients	**X**	
Specific cases (bridges, tunnels, viaducts)		**X**
RAILWAY SPECIFIC		
Wheel and rail roughness		**X**
Differentiation between track/support structure	**X**	
Differentiation between engine noise, rolling noise,		**X**

aerodynamic noise		
Differentiation between different types of vehicles/ locomotives		X
Specific cases (bridges, tunnels, viaducts)		X
INDUSTRIAL SPECIFIC		
Point, line, area source	X	
Lateral diffraction around obstacles	X	
AIRCRAFT SPECIFIC		
Aircraft performance as a function of air parameters, aircraft type, engine type, TOW	X	
Differentiation between different take off procedures and between different approach procedures		X
Terrain shielding / screening effects		X
Ground absorption (correction for hard ground at the receiver)		X
OTHER REQUIREMENTS		
Scientific evidence		X
Validation of the method/extent of validation		X
Royalties / IPR issues	X	
Easiness of implementation into software (complete and clear description)		X
Availability of parameters and input values databases		X
Frequency of update of database		X

5. EVALUATION OF AND PRESELECTION AMONG EXISTING NOISE ASSESSMENT METHODS

The evaluation exercise started through the literature survey described in chapter 3. In the evaluation, it was also included the info reported by the EU MS through the questionnaire on noise mapping methods sent by the former WG-AEN and finally submitted to MS in the course of 2008 by DG ENV.

After the info on existing noise assessment methods was identified via the aforementioned sources, the method developers (or the national offices responsible for the methods) were directly addressed to get info about potential updates of the methods and their validation status.

In few cases, DG JRC was informed that the national methods were replaced by international ones or superseded by other national ones. Therefore, for these few cases the methods originally considered in the evaluation exercise were afterwards dropped out from the list of candidate methods. For some methods that information gathered revealed that these methods originally developed for some specific noise sources were further developed to include also other noise sources.

Based on the literature review of chapter 3, the following list of methods was drawn (see table 2).

It should be noted that from the interim methods recommended by the END Directive only the ISO 9613 (industrial noise) is reported in table 2, as for the three other sources (i.e., road, railway, aircraft) more recent methods were developed, thus superseding the so-called “interim methods”.

Table 2: *List of methods considered in the review of existing noise assessment methods*

Road traffic noise method	Country
ASJ RTN 2008	JP
CRTN	UK
HARMONOISE/IMAGINE	EU
NMPB 2008	FR
Nord 2000	DK- FI - IS- NO- SE
RLS90 / VBUS	DE
RMW	NL
RVS	AT
Sonroad	CH
Railway traffic noise method	**Country**
CRN	UK
HARMONOISE/IMAGINE	EU
Nord 2000	DK- FI - IS- NO- SE
Onorm 305011	AT
RMR	NL
Schall 03 / VBUSch	DE
Semibel	CH

Industrial noise method	Country
HARMONOISE/IMAGINE	EU
ISO 9613	EU
Aircraft noise method	**Country**
AzB 2008	DE
ECAC Doc. 29 3rd Ed.-ICAO doc. 9911	EU
(FLULA)	CH
(INM)	US
(JCAB)	JP
(NORTIM)	NO
HARMONOISE/IMAGINE	EU

Some specific circumstances occurred while retrieving info for some of the methods are described below.

Some of the methods included in the evaluation have been provided to DG JRC in their draft stage by courtesy of the developers though not yet officially released. These are: **ASJ RTN 2008, NMPB 2008, Schall 03, AzB 2008**. The latest versions of these methods were considered in this review, assuming that the recent updating of these methods includes more detailed descriptions of source and propagation and also new updated databases, though these are not yet formally approved by the relevant national authorities.

Consequently, in the case of the **German methods** for railway and aircraft noise calculation, the aforementioned updated versions were used as a reference and not the corresponding methods officially implemented in the VBUSch and VBUF (Bundesanzeiger, 2006).

The **NMPB 2008** was declared by the French national authorities to be under the process of being extended also to railway and industrial noise, therefore it was provisionally added to the list of the methods to be evaluated. Unfortunately, these two methods are not yet available, not even in a draft format, so at the end it was not possible to evaluate them.

In the case of the **Nord 2000**, it should be noted that, based on the replies of the developers, this method is described by a set of publications rather than through a single document, therefore, these set of documents were used and referred to in the evaluation of the fulfilment of the requirements mentioned in chapter 4.

Concerning the industrial noise, except for HARMONOISE/IMAGINE, it was not possible to find in literature other recent methods that substantially differ from the calculation procedure of **ISO 9613**, and for this reason no other methods were evaluated concerning this source of noise.

As far as aircraft noise is concerned, it was possible to identify only three methods, AzB 2008, HARMONOISE/IMAGINE and ECAC-CEAC Doc. 29 3rd Ed.. The latter corresponds in full to the method outlined in ICAO Doc. 9911. In literature, sometimes others are referred to as 'methods', namely the US INM, the Japanese JCAB, the Swiss FLULA and the Norwegian NORTIM. After having collected and analysed all related information, it was concluded that these latter cannot be properly considered as 'methods', since they miss a thorough description. Instead, these are software which implement formulas based on the ECAC-CEAC Doc. 29 3rd Ed., on the document SAE-AIR 5662, on the ISO 9613-1, or in turn, in the case of NORTIM, based on the manual of old versions of INM. Databases of flight profiles, NPD (Noise Power Distance) and air absorption are typically developed at national level, given the inconsistencies found between internationally used databases and the national measurements. Moreover, corrections not included in the original documents are included in the software implementations. These corrections consider ground excess attenuation, screening diffractions by obstacles, ground absorption effects, lateral directivity of the aircrafts and terrain height. The methods present in the most recent literature include new corrections not foreseen in the original documents they are referred to. However, since none of these software is thoroughly outlined in one (or more) document explaining the method used, but rather only some of the corrections used are presented, it was decided not to consider them as methods. Nevertheless, the information obtained by the software developers were kept to eventually further fine tune the EU common assessment method at a later stage.

After having consulted the literature, gathered info from the developers of the methods identified, the methods shown in table 2 were evaluated against the requirements for the selection of common noise assessment methods described in table 1.

Only one of the existing environmental noise assessment methods fulfil all the essential criteria, that is the **NORD 2000**, however, this method does not explicitly contain a part for industrial noise assessment, nor it includes aircraft noise. Another method, the **HARMONOISE/IMAGINE**, instead includes also industrial and aircraft noise, and fulfils the same criteria as the NORD 2000 for road traffic and railway traffic noise, except that on IPR issues and possible associated royalties that were pending in the beginning of the evaluation exercise. However, during the evaluation exercise, communications in written reached DG JRC from most of the former HARMONOISE/IMAGINE project partners who have officially expressed their willingness to remove IPR issues relating to most critical parts published by the two projects which are essential to be considered in this exercise as well.

Among *those evaluated for road traffic noise only*, **ASJ RTN 2008, NMPB 2008**, and **RVS** are those most closer to fulfil all the essential requirements, though limited to the description of only one noise source (road traffic). Therefore, before finalising the proposed common noise assessment method, it will be crossed checked if elements included in these methods are missing in the proposed common noise assessment method(s). In such case, those parts will be integrated in the proposed common assessment method(s).

Between those evaluated for railway traffic noise only, **Schall 03** is the one most closer to fulfil all the essential requirements (except that the meteorological influence is not considered), however it applies only to railway traffic noise. Therefore, before finalising the proposed

common noise assessment method, it will be crossed checked if elements included in this method are missing in the proposed common noise assessment method. In such case, those parts will be integrated in the proposed common assessment method.

Between those evaluated for industrial noise only, **ISO 9613** fulfils all but one of the essential requirements (meteorological influence is fixed) but again it applies only to industrial noise.

Between those evaluated for aircraft noise only, the **HARMONOISE/IMAGINE** method fulfils all but three of the essential requirements and it was developed also for the other three noise sources (road traffic, railway traffic, industrial), therefore this method would have, if finally qualified, many elements in common with the road traffic, railway traffic and industrial noise methods. However, in the aforementioned Workshop, concerns about using the HARMONOISE/IMAGINE method for aircraft noise were expressed by the Workshop's participants, as this method is missing essential parts such as the segmentation technique and the input values database which cannot be easily prepared. Instead, **AzB** fulfils all but four essential requirements and all but three of the recommendable requirements, and **ECAC-CEAC Doc. 29 3rd Ed.** fulfils half of the essential requirements and all but two of the recommendable requirements. Therefore, given that no method fulfils all essential requirements for aircraft noise, and given that HARMONOISE/IMAGINE does not meet the aforementioned essential requirements, the best of the two other candidates (i.e., AzB and ECAC-CEAC Doc. 29 3rd Ed.) for aircraft noise will be considered as a basis for preparing the common noise assessment method for aircraft noise. The AzB fulfils more essential and recommendable requirements than the ECAC-CEAC Doc. 29 3rd Ed. and in addition is the closest one to the approach of the Nord 2000 and HARMONOISE/IMAGINE in the sense that: it includes proper assessment position at 4.0 m height, it describes the source in terms of source sound power and source directivity, and separates the propagation into geometrical divergence, air absorption and ground effect. It describes all source and propagation as a function of octave band spectra, in line with the requirement that "preference will be given to solutions suggesting common parts between the road, the railway, the industrial and the aircraft noise calculation methods.

6. CONSCLUSIONS AND NEXT STEPS

Consequently, on the basis of the aforementioned considerations, it was concluded that:

- **HARMONOISE/IMAGINE** and **Nord 2000** will constitute the basis of the common assessment method for road traffic, railway traffic noise and industrial noise, and **ISO 9613** will be the basis for the common assessment method for industrial noise.

- For aircraft noise, it is proposed to consider the **AzB** and **ECAC-CEAC Doc. 29 3rd Ed.** and possibly integrate the best of each of the two methods to ensure that as many as possible of the essential requirements are met. It is necessary to mention that the European Commission, in the Commission Recommendations of the 6th of August 2003 (2003/613/EC), stated that "*attention should be paid to the revised version of the method when it is adopted by ECAC so as to allow, if appropriate and considered necessary, for the new method to be introduced in Annex II of Directive 2002/49/EC as the recommended method for aircraft noise computation*". Therefore, also in this case, an attempt will be done to liaise with ECAC-CEAC to establish if there is an interest of updating the ECAC-CEAC Doc. 29 3rd Ed. with appropriate elements to align with the most recent noise mapping requirements and standards.

- As mentioned above, since four recently developed/updated methods (**ASJ RTN 2008**, **NMPB 2008**, **RVS**, **Schall 03** fulfil the biggest part of the essential requirements and are the result of research investigations recently concluded, they will be considered as supplementing the process of the development of the common noise assessment methods. This will be achieved through integrating those of the characteristics of the aforementioned four methods that present or can be expected to exhibit a far better formulation of one or more parts of the common noise assessment method that could result to a large improvement compared to the corresponding parts of the main candidate method qualified.

The next steps of the roadmap for the preparation of the common noise assessment methods are the following:

1. A workshop is planned to take place on 8-9 September 2009 in Bruxelles, where the alternatives for the several parts of the common noise assessment methods will be presented and discussed among DG ENV, DG JRC, EEA Experts Noise Panel and the group of EU noise experts invited and accepted to support this process. During the month of August 2009 contacts were taken with the developers of the methods qualified to form the basis for the preparation of the noise common assessment methods. A table with the parts of the methods that will be discussed in the Bruxelles Workshop was prepared and submitted to the developers of the qualified methods who were asked to fill in the appropriate parts of the table corresponding to their methods. This will allow comparison between different alternatives for the various parts that will constitute the common noise assessment methods.

2. Before the end of 2009 a second Workshop will be organised aimed at conceptualising the '*fit for purpose*' framework for the noise common assessment methods (i.e. algorithms, settings and default set of input values).

3. Drafting of the common noise assessment methods: a draft report containing a transparent and usable version of the noise common assessment methods (algorithms, settings and default set of input values) will be prepared by DG JRC assisted by a small number of noise experts and delivered to the Network of noise experts involved in this exercise for comments.

4. A final report on the common noise assessment methods will be prepared and delivered to DG ENV for commenting and further submission to the Noise Regulatory Committee.

REFERENCES

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