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Differences among European noise mapping methods

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This article outlines the rationale behind and the means developed for performing the exercise on equivalency among the national assessment methods used in the EU Member States against the interim methods established by the Environmental Noise Directive 2002/49/EC (END). Through this exercise potential differences among noise maps of L_{den} and L_{night} levels produced following the EU Interim methods and those produced following other national methods used in the EU MS will be revealed and quantified. L_{den} and L_{night} are the two indicators required by the END defined at a position of 4m height and 2m away from the façade of a building. Four different draft protocols along with potential criteria for assessing the equivalency of the methods were prepared by the Joint Research Centre on behalf of DG ENV for road, railway, industrial and aircraft noise. This article focuses on the conception and limitations of the four draft protocols and summarises the main characteristics of the test environments conceived for each protocol.

1 Introduction

Key elements of the Environmental Noise Policy and of the Environmental Noise Directive 2002/49/EC (END) in the EU [1] are: (a) the monitoring of environmental noise by requiring competent authorities in Member States to draw up "strategic noise maps"; (b) informing and consulting the public about exposure to harmful noise levels; (c) addressing local noise issues by requiring competent authorities in the MS to draw up action plans and (d) developing a long-term EU strategy on environmental noise monitoring and abatement.

Concerning the assessment of environmental noise, Article 6, par. 2 of Directive 2002/49/EC foresees that, until common assessment methods are adopted interim methods shall be used for the assessment and mapping of noise (Annex II) or national methods provided that these methods give equivalent results to the interim methods stipulated in the Directive.

Concerning the methods used, the recent communication from the MS to DG ENV revealed a differentiation in the methods used by the MS and also the ways they proved the equivalency of their national methods against the interim ones. Some MS exclusively use national methods for all four noise sources (i.e., road traffic, railway traffic, aircraft and industrial noise), others allowed using more national methods for the same source or even national methods for some noise sources and interim for the rest of them. As far as the proof of equivalency is concerned, some MS simply declared proof of equivalence without demonstrating it, whereas others although using the same indicators as the adapted interim methods (i.e. L_{den}, L_{night}) stated that their methods will never produce equivalent results. The impossibility to produce equivalent results was attributed to the fact that equivalence cannot be exclusively based on the assessment methods used but also to the quality of input data and interpretation of the Directive, yet two different assessment methods will never produce identical results.

2 Rationale and boundaries of the exercise on equivalence

As the European Commission has the duty to ensure consistency of assessments and equivalency of methods as well as the production of comparable data concerning environmental noise across the EU, DG ENV to effectively assist MS in demonstrating the equivalence in a fast and cost-effective manner charged JRC with preparing draft protocols to check the equivalency on a common, objective and impartial basis.

The application of these protocols, besides being strictly useful for the exercise on equivalence will also produce important information to be used by the EC for the comparability of the data produced so far across the MS.

Comparability of information is essential for the public but also for the future development of noise policy and the review of the directive. Moreover, if the results of this exercise on equivalency will reveal large differences among the different methods used, this would be a strong argument in favour of future harmonisation of the assessment methods.

Since the END does not require reporting on the way the input values were collected, in the context of this exercise on equivalency it will not be checked how the input values were obtained by MS. Besides this is not required by the END also it is statistically not influential for large numbers of receiver points. Even if for a single point or cross section the input values are collected with an associated uncertainty, for large number of receiver points due to the central limit theorem the average will be close to the true average value.

Another boundary of this exercise is that no evaluation will be performed on the specific software used to perform the calculations and on how the number of people exposed is derived (on large numbers the method used to assign the people to the buildings is also statistically not relevant).

3 Conception and limitations of the draft protocols

Four draft protocols (for road traffic, railway traffic, aircraft and industrial noise) were developed on the basis of the recommendations made in two consultant meetings organised by the JRC for:

- Defining the test environment for each protocol
- Providing sets of input values to be used for simulating various configurations by employing both, the interim and the national methods.

For each protocol, the test environment (terrain, buildings, barriers, assessment positions, noise source configuration, meteorological situations) was appropriately designed to represent some typical configurations of the noise source under assessment, as well as, a combination of all major situations occurring in a real environment, including urban and rural areas in the EU MS.

For each configuration, a set of input values was defined for running the simulations with the interim and the national methods.

The four protocols (test environment and associated set of input values) were defined bearing in mind the following requirements and boundaries of the entire exercise:

1. The reference point is the interim method and not the national method. The latter should prove to be equivalent to the former and not vice versa.

2. The equivalency of the national method to the interim method should be evaluated using an approach as impartial as possible. Nevertheless, it is considered that different MS may have specific situations representative of their own country. Therefore, the fact that some methods could give equivalent results in some MS, but not necessarily in all of them was fully considered in the definition of the protocols.

Considering the aforementioned specific situations representative of each country, the MS will be asked to verify whether the sets of configurations defined in the four protocols, which are considered common for Europe, are suitable for their case. Otherwise, the MS shall declare the sets of configurations that fit to the scenario commonly encountered in their country.

3. The aim is to check the equivalency of the national methods but not the way these methods are implemented in software. However, as errors in software implementation may be an influential source of error in the overall analysis, these shall be considered by the DG ENV and JRC using at least three different software implementations of each method.

4. The assessment positions are as defined by the END at 4 m height and 2 m in front of a most exposed façade. Assessment positions are meant to be representative of the most exposed façade, bearing in mind that the general objective 1 of the END is "to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise".

5. Comparisons shall be possibly performed for noise levels higher than L_{den}/L_{night}= 50 dB(A);

6. The number of configurations corresponding to the test environment of each one of the four noise sources were selected in a way to cover a large set of realistic situations representative of those to be mapped according to the European Noise Directive 2002/49/EC.

7. No evaluation will be performed on how the population exposed is derived. The requirements of the END are limited to the computation methods, and do not specify to check the specific technique adopted to attribute exposure population levels. Therefore, the exercise on equivalence will be limited to proof that the levels calculated at 4 m height and 2 m away from the façade are equivalent or not.

8. The calculated noise levels to be reported by the MS will be compared to the ones obtained internally by the EC (DG ENV and JRC) strictly using the interim methods.

9. The MS will be required to demonstrate how they performed the calculations. This is to ensure that the results are reflecting the exact requirements and procedures described in the national method and eventual related documents, standards and databases referred to in the corresponding national regulations officially declared in the EC (DG ENV).

10. For road traffic noise, railway traffic noise and industrial noise, the test environments are designed to reflect:

- A free field situation, for identifying the major differences among the methods due to the propagation above the terrain only.
- An area with buildings, consisting of maximum two rows of buildings, for testing the response of the different methods at the assessment positions as defined by the END in the case of simple diffraction of noise over a building.
- A complex building setting, for evaluating the behaviour of the methods in complex situations in which several reflections and diffractions occur.

11. To avoid testing the software performance that becomes critical if many reflections are introduced, two reflections only were considered in this exercise.

12. For aircraft noise, based on traffic data on major European airports, a set of representative aircrafts was identified and standard flight procedures applied.

13. The definition of the input values was based on a selection of the most frequent situations occurring in the MS, bearing in mind that the scope of this exercise on equivalence is to point out those differences (among the methods) that mostly affect the noise maps to be produced.

14. Various configurations are well described through a complete specific set of parameters, however allowing flexibility for the national methods to use their own databases of specific input values.

15. A grid of assessment points was defined to check the correct spatial evolution of the predicted noise levels.

The four draft protocols shall be finalised on the basis of the comments received from DG ENV and the experts of the MS before, during and after the Noise Committee meeting between EC and MS held on 7th May 2008 in Brussels.

4 Description of the test cases

Each protocol is based on:

- An ideal (not real) test site specifically developed for checking the equivalency of the methods.
- Representativeness of real situations, neither too close nor extremely far from sources (e.g.: 25m – 500m for road, rail, industry, 30km X 30km for aircraft)
- Source conditions with traffic type typical of situations in urban and rural environments to be mapped following the END 2002/49/EC
- Propagation, consisting of air absorption, reflection, diffraction, screening tested for several distances from source and a number of cross sections for each noise source.
- In general two meteorological conditions (i.e., favourable and/or homogeneous) were considered.

Receivers are placed at representative positions on the cross sections at a height of 4m (except for aircraft methods

which calculate at 1.2 m). A detailed description of the test environments for all four noise sources could be found in the JRC report [2] available through the DG ENV CIRCA website.

An example of a test site for railway noise is given in Fig. 1. It consists of a building and combinations of barriers. The building facing the railway line is a U-shaped and the positions of the buildings are at increasing distances from the source. The positions were studied to avoid having contributions of the source from source positions far from the orthogonal line to the source itself. In the lower part of the figure a complex buildings set up is checked to have an indication about the behaviour of the method under a complex set of diffractions and reflections.

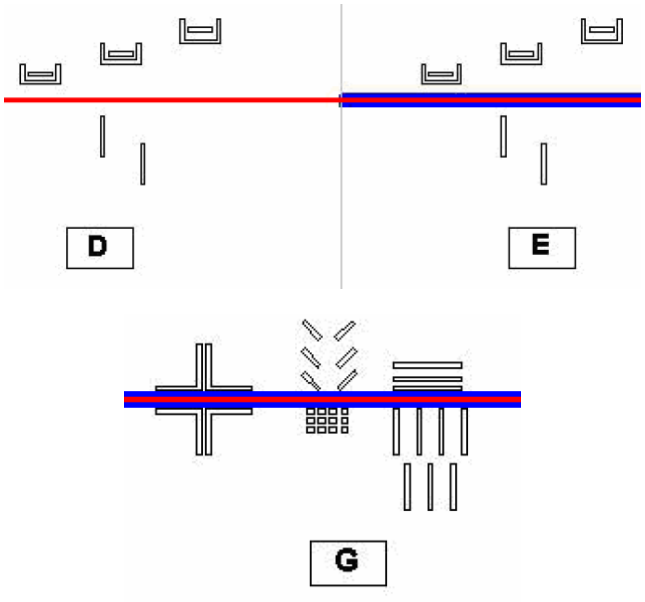

Fig.1 example of two railway noise cross sections for evaluating differences among the methods

In the case of aircraft noise, 19 aircraft types are selected among the most common ones present in major European airports (as from recent data on the airports movements). A straight approach, a straight take off and a curved take off is modelled, and data are given in general terms to set up and perform the test. The protocol requires a certain number of movements per day, which were derived to obtain reasonable levels at the ground. Adding up the several movements which are required to be used, a simulation of the levels around an ideal major airport is then obtained.

5 Potential assessment criteria

In the context of the exercise on equivalency any differences among the national methods and the interim ones could be assessed on the basis of one or more indicators through which the following three differences can be evaluated:

1. ***Percentage of*** ($L_{interim} - L_{national\ method}$) at the single assessment points falling outside the values calculated by the interim method $L_{den} \pm 2\sigma$ or $L_{night} \pm 2\sigma$, where σ is estimated by using different software.

2. ***Overall averaged difference*** L_Δ (considering possible compensations between points for which the difference ($L_{interim} - L_{national\ method}$) is positive and points for which the same difference is negative).

3. ***Percentage differences of people exposed*** to the several bands: $p_{50\text{-}55}$, $p_{55\text{-}60}$, $p_{60\text{-}65}$, and $p_{65\text{-}70}$.

The aforementioned indicators can be applied under the following hypotheses:

- the calculations made by the MS are performed on a large number of cross sections, therefore the number of buildings affected by different noise levels can be approximated by a continuous function of the noise levels (also, this corresponds to the fact that a shift in the noise contours will continuously increase/decrease the number of buildings affected);
- a number of people is attributed to the same buildings regardless of the noise mapping method adopted, and therefore if the new method attributes higher noise values to that building its population will be exposed to these new values;
- the number of people considered in the maps is very large (and therefore it is possible to assume that it is equivalently, homogeneously and continuously distributed between buildings).

Under these hypotheses, the following can be assumed:

- a shift in the noise levels at a given position due to different methods will result in a shift of a certain amount of people from one band to another (not necessarily the next one, if the shift is larger than 5 dB!);
- the shift in bands of a certain amount of people $\boldsymbol{x_i}$ from the i-th band with $\mathbf{X_i}$ people exposed to the j-th band with $\mathbf{X_j}$ people exposed can be approximated if the hypothesis of continuous and homogeneous distribution of cross sections and people in buildings holds true (e.g.: when the difference is between 0 and +2.5dB) as follows:

$$x_i = \frac{1}{\Delta_{band}} \int_{L_i + L_{\Delta i}}^{L_i + \Delta_{band}/2} X_i + \left.\frac{dX}{dL}\right|_{i \to j} \left(L - L_i\right) \quad dL \qquad (1)$$

where:

Δ_{band}=5 (the width of a band, e.g.: 55-60 dB)

$L_{\Delta i}$=overall averaged difference L_Δ corresponding to the i-th band

L_i=central band level (e.g.: for 55-60 dB band L_i is 57.5 dB)

$dX/dL_{i->j}$=derivative of the X(L) function in the i-th band and when there is a shift between the i-th and the j-th band (each band is 5dB wide).

Since in general the X(L) is only a discrete function every 5 dB (because the reported values are cumulative values of population exposed in terms of 5dB bands), an approximation is introduced with:

$$\left.\frac{dX}{dL}\right|_{i\to j} = \frac{\Delta X_{i-j}}{\Delta L_{i-j}} \qquad (2)$$

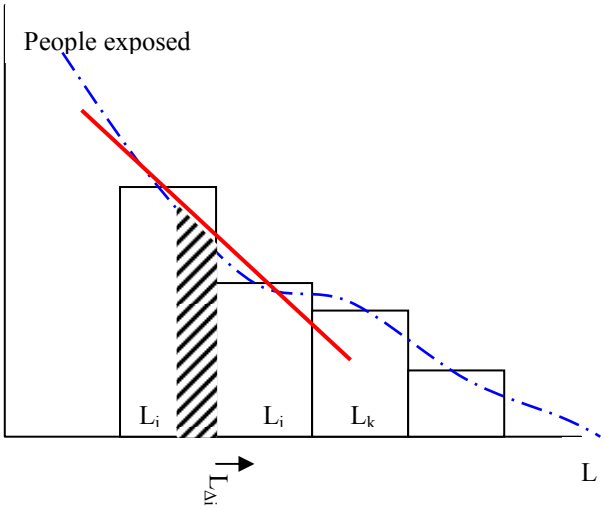

Fig. 2 Continuous and discrete population distribution among noise levels

The ***percentage difference of people exposed*** in the j-th band (between the i-th band and the k-th band) then will be:

$$p_j = \frac{x_i - x_j}{X_j} * 100 \qquad (3)$$

An example of the effects of a constant shift of 2 dB between the interim and the national method is given in Fig. 3. If the x_i and x_j amount of people move to the next band, the percentages difference of people exposed are reported in the same figure. It can be noticed that in the case of the band for which the population is most exposed (i.e., more than 75 dB) an increase of 2dB will mean a triplication of the exposed population. The values presented were taken from one of the first set of data reported for agglomerations in the case of road traffic noise. In this case the number of people exposed to the highest noise levels according to one method would be 3000, whereas according to the other method will be 10000. Based on experience, it seems that the 2 dB difference is an optimistic example of what differences might be encountered and mean in real cases. It should be underlined that, regardless of the results of this exercise on equivalency among the national methods used in the EU members states and the interim methods, EC is unlikely to ask MS for retrospective re-analysis of existing noise maps.

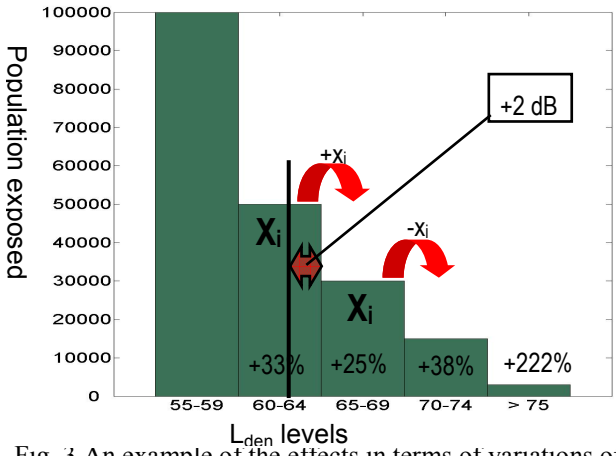

Fig. 3 An example of the effects in terms of variations of population exposed per each noise band if the 3rd criterion is adopted

6 Conclusion

- Almost no information is reported yet from MS on the different noise values calculated for analogous situations in different MS.
- At the moment, it is not possible having a comparable assessment at EU level of the exposure of population at harmful L_{den} and L_{night} levels, however, this is needed for undertaking effective health protection measures.
- Based on past know-how, differences for assessment of single positions can easily exceed 10 dB between MS and eventually, within the same MS, depending on the quality of the input values.
- Harmonisation of the assessment methods is necessary, otherwise the following principle should be accepted:

  In case a MS has adopted a different assessment method, and the equivalence of the results simply means that just the same indicators are used, it might happen that**:**

  - In two different countries, the same airplane, will have different impacts in terms of population exposed (it was noticed that this could easily cause the doubling of the population exposed), however,
  - in a related environmental field like green gas emissions, for example, could it be acceptable that an airplane in a MS A will introduce two times more CO_2 whereas in MS B only ½ of CO_2?
- It is evident that MS made large efforts to produce noise maps**.**
- Nevertheless the problems arising from non equivalent results should be faced.
- The equivalence protocols will be helpful for estimating the average differences between MS and for providing the public and the EC with

useful info for comparing and appropriately using the results of the 1st round of noise maps.

References

[1] Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise, 25 June 2002.

[2] JRC Technical report to DG ENV on "Draft protocols for checking the equivalence of national noise mapping methods against the interim methods", February 2008 (DG ENV CIRCA web site: http://circa.europa.eu/Public/irc/env/noisedir/library)