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Comparison of engineering models of outdoor sound propagation: NMPB2008 and Harmonoise-Imagine

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Several models of outdoor sound propagation can be used to predict transportation noise for noise mapping or transportation noise studies. We present here a comparison of noise attenuations predicted by a) the French engineering model NMPB 2008, designed for railway, road or industrial noise, b) the engineering model elaborated in the European Harmonoise/Imagine projects. The comparison has first been done by comparing the deviations between models for calculated sound attenuation for both homogeneous and downward propagation conditions and for seven experimental site configurations. Some significant deviations can be observed mainly for high frequencies and also for homogeneous propagation conditions. A comparison between calculated and experimental sound attenuations is also presented for each model, on the basis of five road noise experimental campaigns, where each site is representative of different common topographies. Some statistically significant deviations between both mean and standard deviation are observed between the two models : the NMPB 2008 model appears to have better trueness and precision than the Harmonoise/Imagine model.

1 Introduction

Several models of outdoor sound propagation can be used to predict transportation noise for noise mapping or for impact studies of transportation noise. The reliability of a prediction model can be characterized by its trueness (difference between the mean of predicted values and reference values) and by its precision (dispersion of the predicted values). Some comparisons between models have been published concerning the modelling of the source emission (see [1] for example), but the existing published comparisons for the modelling of the propagation consist only in comparison of formulations [2] or consider only a few experimental cases with simple topography [3]. We present here an extensive comparison of calculated results between the Harmonoise/Imagine model and the French NMPB 2008 model.

The Harmonoise model [2][4] has been developed in the last 10 years in order to include more physically observable influences and to be a candidate to the common European model for noise mapping. The NMPB 2008 model [5][6] is the French model for railway and road traffic noise and is an evolution of the former NMPB-Route 96 model. NMPB 2008 is currently the base for the definition of the propagation part of the so-called CNOSSOS-EU harmonized framework for the implementation of the Environmental Noise Directive 2002/49/EC. NMPB and Harmonoise are both engineering models based on a simplified ray tracing approach, but they differ in several ways: the Harmonoise model rely on more physical formulations, but needs more precise input parameters and rather high calculation times (Probst [3] gives calculation times 50 times higher than for other models), whereas the NMPB 2008 is based on simplified but fast formulations and has been validated with several extensive experimental campaigns [7]. It is not the purpose of this paper to weight the pros and cons of these two approaches but the aim is here is to compare the attenuations calculated by these two models in order to investigate the reliability of each model [8].

We first present the methodology adopted for the comparison (section 2). We present next the results of the comparison (section 3) for calculated results between models and for calculated results against experimental results for each model. Some information are also given about the trueness and the precision of each model.

2 Methodology of comparison

2.1 Protocol

The comparison of models has been carried out in two ways for several sites. The first one is a comparison between calculated attenuations by each model and the second one is a comparison for each model between calculated and measured attenuations. Both comparisons are based on the calculation by each model of the attenuation equal to the difference between the sound level at the receiver closest to the road and noise levels at other receivers. Therefore, the comparison only accounts for differences in propagation modeling and not in source modeling.

The modeling of a site (topography, position of receivers, sources) and the ray tracing process has been done with the same computer code for both models. Only the calculation of attenuations differs by using two separate codes: a code for NMPB 2008 developed in scilab by LRS [9], and the dynamic link library *P2P* (version 2.0.19) [10] developed by CSTB during and after the Harmonoise project. Two meteorological conditions have been considered: homogeneous and downward conditions. Attenuations have been calculated for 1/3 octave bands from 100 Hz to 5 kHz, and also in A-weighted broadband. Some details of the modeling adopted for the comparison are given below:

Source: each road traffic source has been modeled as a straight distribution of point sources along the axis of each lane, at a height of 5 cm from the ground. The distance between two consecutive points was 5 m. Each road has been considered to have an infinite length (in practice the length has been set at 4000 m).

Topography: the vertical section of the ground has been repeated in an identical manner along the axis of the road.

Ground absorption: the road has been considered as reflective (G = 0 for the NMPB, sigma = 20 000 $kNsm^{-4}$ for Harmonoise) and the ground outside the road has been considered as grassy ground (G = 1 for the NMPB , sigma = 300 $kNsm^{-4}$ for Harmonoise).

Meteorology: Harmonoise allows to model meteorological effects with a lin-log definition of the sound speed profile [4]. The homogeneous condition has then been modeled considering the two log-linear coefficients as 0. For reasons of consistency, the definition of downward conditions of NMPB has been adopted for the the sound speed profile of Harmonoise (linear sound speed profile with a 0.07 s^{-1} gradient): the Harmonoise linear coefficient has been set to 0.07 s^{-1} and the log coefficient to 0.

2.2 Test sites

The two kinds of comparison have been done using several test sites from experimental campaigns conducted during the validation of the NMPB model (sites of St Omer, Massiac, Molsheim and Mulhouse – see Figure 1 to Figure 5) and those conducted during the Harmonoise project (La Crau and Unna - see Figure 6 and Figure 7). These sites cover different topographies that allow to test the models for many acoustic phenomena: ground effects (all sites), ground diffractions (St Omer, Massiac, Molsheim, Mulhouse), noise barrier diffraction (Unna), complex topography (Massiac), trench road (Molsheim, Mulhouse) , viaduct configuration (St Omer), …

Each site has a different topography, except for Molsheim North and Molsheim South that only differ from their orientation from the road and from some receivers positions.

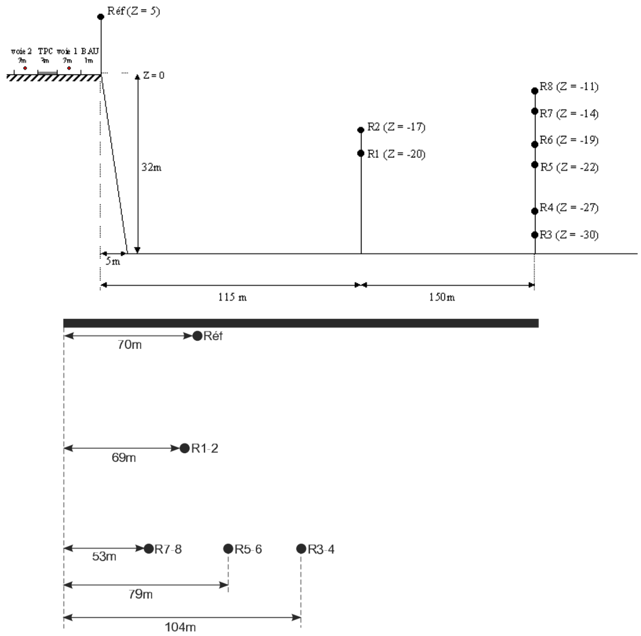

Figure 1: St Omer site. Vertical cut (top) and horizontal cut (bottom).

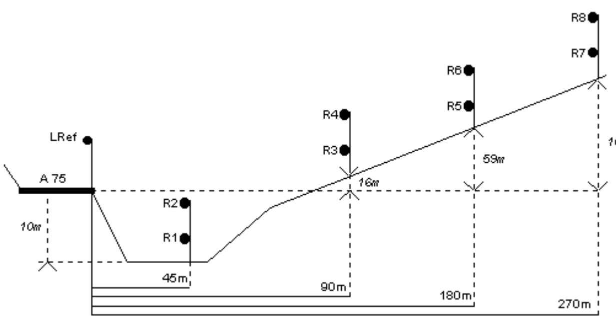

Figure 2: Massiac site (receivers heights : 2m and 5m)

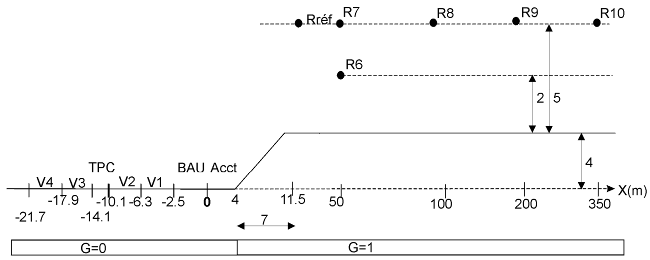

Figure 3: Molsheim site (North)

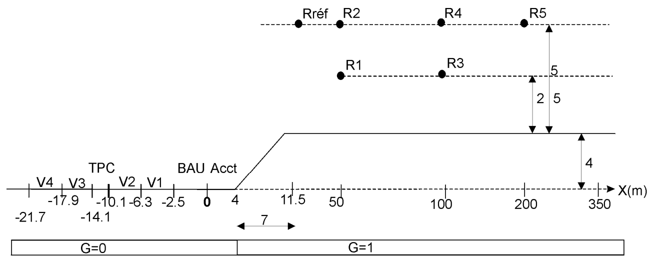

Figure 4: Molsheim site (South)

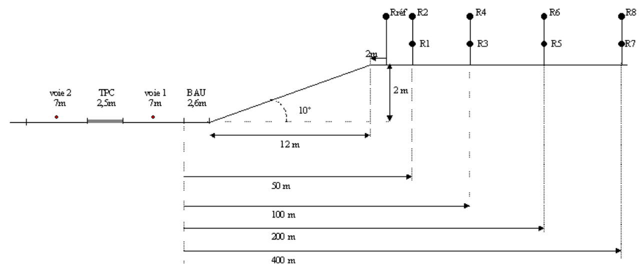

Figure 5: Mulhouse site (receivers heights : 2m and 5m)

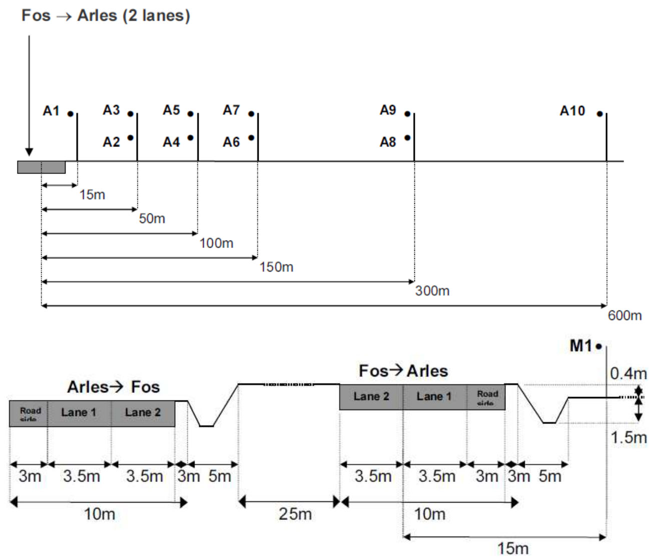

Figure 6: La Crau site (receivers heights : 1.5m and 4m). Receiver positions (top) and road description (bottom).

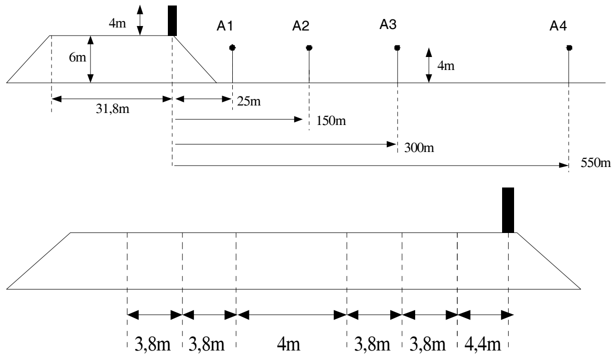

Figure 7: Unna site (receivers heights : 1.5m and 4m). Receiver positions (top) and road description (bottom).

3 Results

3.1 Comparison between calculated attenuations

For each model, the attenuations are calculated for homogeneous and for downward conditions. Figure 8 present the difference between attenuation calculated by NMPB and by Harmonoise for all sites, for 1/3 octave band and A-weighted broadband. In this representation, the width of the boxes is related to the dispersion (the top and bottom borders of the boxes give respectively the first and the third quartiles), the bold line gives the median and the circles are for potential outliers. The deviations between the two models strongly depend on frequency and are much higher for high frequencies: mean deviations can exceed 10 dB(A) for homogeneous condition and for high frequencies (Figure 8). The dispersion of deviations is also more important for frequencies higher than 3 kHz.

The deviations are higher for homogeneous conditions than for downward conditions: the average broadband A-weighted deviations are about 2 dB(A) and 1 dB(A) for Harmonoise and NMPB respectively (Figure 8). Harmonoise provides average noise levels higher than the NMPB 2008 does for both meteorological conditions. The dispersion of deviations is also higher in homogeneous propagation condition than in downward conditions.

For receivers where diffractions exist (*e.g.* St Omer and Unna), Harmonoise provides a mean sound attenuation higher by about 1.5 dB(A) than NMPB. When diffractions are not predominant, Harmonoise provides mean sound attenuation lower by about 2.5 dB(A) to 4 dB(A).

Although there are some differences between the two models, for frequencies lower than 1kHz the average deviations remain relatively small and are close to what may be expected for a comparison between two noise engineering models. However, for some particular configurations, the average A-weighted deviations may be more important in homogeneous conditions (typically greater than 3 dB(A)), as well as for 1/3 octave band above 1kHz.

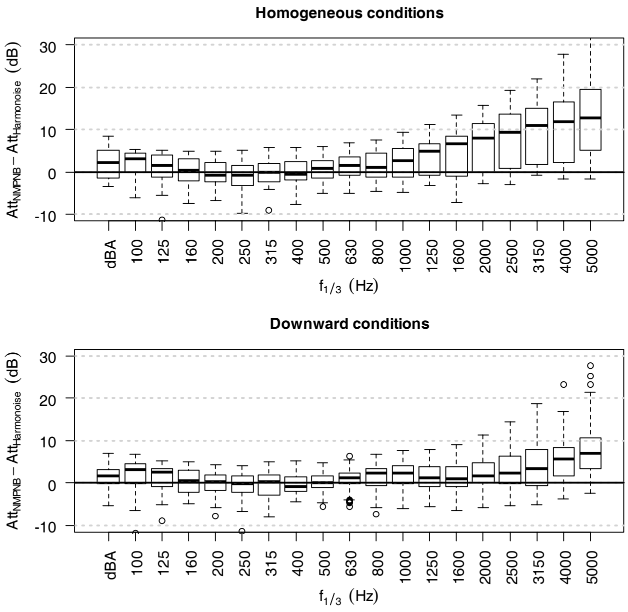

Figure 8: Boxplots of deviations between attenuations calculated with NMPB and with Harmonoise (all sites). Homogeneous (top) and downward conditions (bottom)

3.2 Comparison with experimental data

For each model, the deviations between calculated and measured attenuations were calculated for the 32 receivers locations coming from five experimental sites among those presented above: Massiac [11], Molsheim N. [12], Molsheim S. [12], Mulhouse [13] and St Omer [14]. Data from experimental sites of Harmonoise campaigns haven't been used because of missing data. The comparison is based on a total of 218 mid-term measurements estimated either on the day period (6h-22h) or on the night period (22h-6h). For each mid-term period and each receiver, the attenuation is calculated by each model using the experimental probabilities of occurrences of downward conditions.

The mean deviation between calculated and measured attenuations is closer to zero for NMPB (-1.0 dB(A) for Harmonoise and -0.3 dB(A) for NMPB, Figure 9). Deviations are more dependant of the site configuration for Harmonoise than for NMPB (Figure 10) and the dispersion of deviations is higher for Harmonoise (Figure 9 and Figure 10). A statistical analysis indicates that the distribution of deviations is gaussian for NMPB but not for Harmonoise (statistical tests of Shapiro-Wilk: p-value<5% for NMPB and p-value>5% for Harmonoise). Moreover, less than 35% of the absolute values of calculated attenuations exceed the measured attenuations by 2 dB(A) for NMPB, whereas this proportion exceeds 60% for Harmonoise (Figure 11).

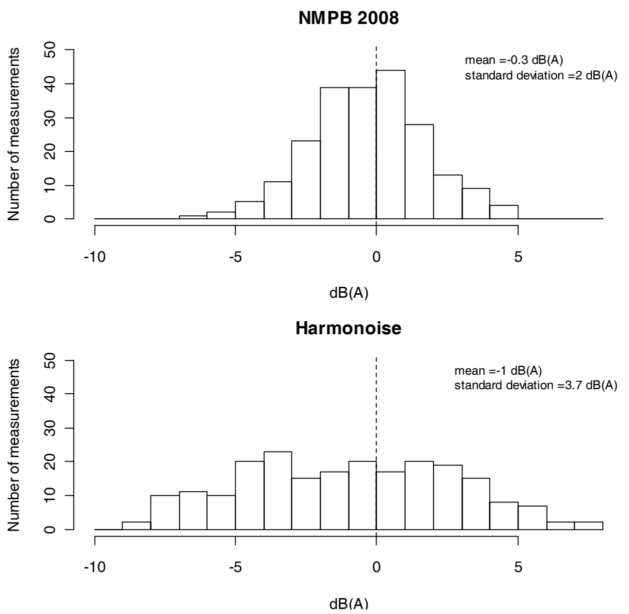

Figure 9: Distribution of deviations between calculated and measured attenuations.

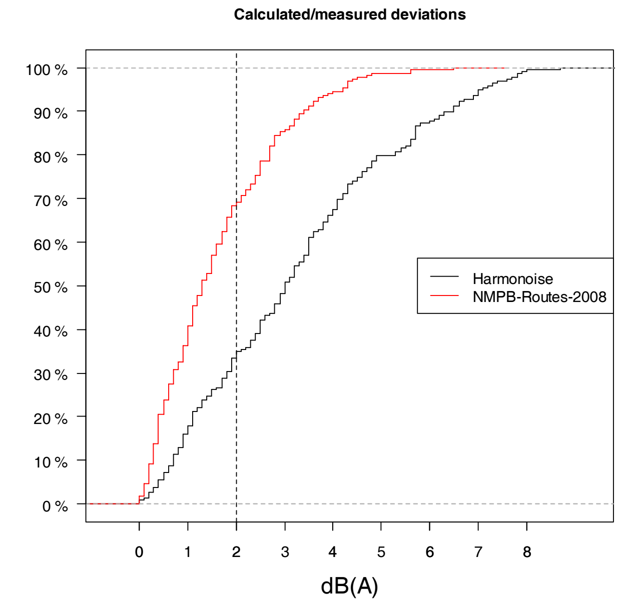

Figure 11 Empirical cumulative distribution function of deviations between calculated and measured attenuations calculated.

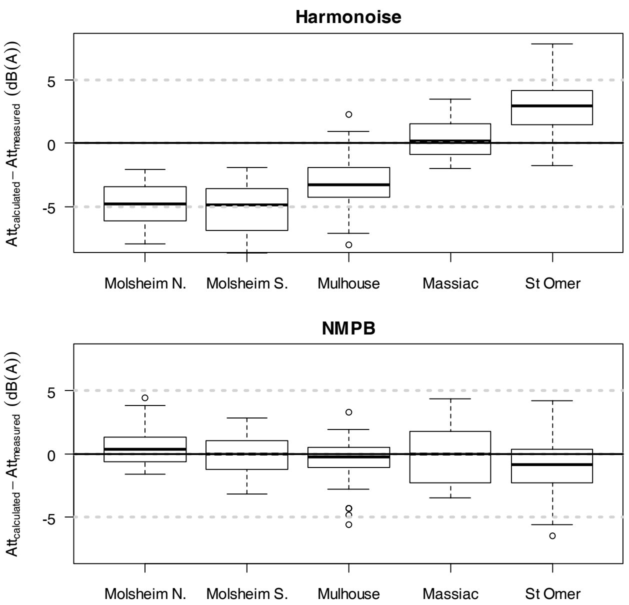

Figure 10: Boxplots of deviations between calculated and measured attenuations.

3.3 Estimation of the trueness and of the precision of the models

The trueness of a model accounts for its ability to give predictions as close as possible to reference values. The reference values used here are the measurements results and the trueness of each model is estimated by calculating the mean deviation between calculated and measured attenuations, for each model. A statistical analysis indicates that the trueness of the two methods are significantly different (Wilcoxon and Student-Welsh statistical tests, p value<5%) and that the trueness of NMPB is better than the trueness of Harmonoise: the mean deviation of NMPB is -0.2 dB(A), with a 95% confidence interval of [-0.5 dB(A), 0.01 dB(A)], and -1 dB(A) for Harmonoise, with a 95% confidence interval of [-1.4 dB(A), -0.4 dB(A)].

The precision of a model accounts for its ability to give predictions as little dispersed as possible. The precision of each model is estimated here by using the standard deviation of the deviations between calculated and measured attenuations of each model. A statistical analysis indicates that the precisions of the two methods are significantly different (Bartlett and Cochran statistical tests, p value<5%) and that the NMPB method is more precise than the Harmonoise method (standard deviations of 2 dB(A) and 3.7 dB(A) respectively).

However, even if the difference of the precision and the trueness of each method are statistically significant, it should be noted that it is rather moderate considering the comparison between two engineering models.

4 Conclusion

A comparison between the engineering models of road traffic noise NMPB 2008 and Harmonoise has been presented. Two kinds of comparisons have been considered: the first one is a comparison between calculated sound attenuations for homogeneous conditions and for downward conditions, the second one is a comparison of calculated and measured sound attenuation for each method. Comparisons only account for the propagation modeling of the two models and do not reflect differences that may exist in the modeling of the noise emission.

On the basis of the considered experimental sites, the comparisons provide the following conclusions : a) the Harmonoise model is less precise and its predictions are more dispersed than for NMPB: the precisions have been estimated as -1 dB(A) for Harmonoise, with a 95% confidence interval of [-1.4 dB(A), -0.4 dB(A)], and as -0.2 dB(A) for NMPB, with a 95% confidence interval of [-0.5 dB(A), 0.01 dB(A)] ; b) sound attenuations calculated with NMPB 2008 are distributed according to a gaussian law, whereas they are distributed as a uniform law for Harmonoise ; c) less than 35% of calculated absolute value of attenuations exceeds the measured values by more than 2 dB(A) for the NMPB 2008 whereas this proportion exceeds 60% for Harmonoise.

Considering what can be expected from a comparison between noise engineering models, it is reasonable to consider that the differences between the two models are rather small. It is however interesting to notice that NMPB 2008 provides predictions that follow a gaussian distribution, when compared to measurement results, which give a better precision and smaller uncertainties.

Acknowledgments

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