Edinburgh, Scotland
EURONOISE 2009
October 26-28

New French road traffic noise predicting method

- Emmanuel Le Duc, Francis Besnard[1] , Vincent - Guizard Service d'Etudes sur les Transports les Routes et leurs Aménagements (Setra) - 46 avenue Aristide Briand, BP 100, 92225 Bagneux Cedex, France
- Jérôme Defrance Centre Scientifique et Technique du Bâtiment (CSTB) - 24 rue Joseph Fourier, 38400 Saint Martin d'Hères, France
- Sonia Doisy, David Ecotière, Guillaume Dutilleux - Groupe Acoustique - ERA 32 LCPC, Laboratoire Régional des Ponts et Chaussées (LRS),11 rue Jean Mentelin, 67035 Strasbourg Cedex 2, France
- Benoît Gauvreau, Michel Bérengier - Laboratoire Central des Ponts et Chaussées (LCPC) - Centre de Nantes, route de Bouaye, BP 4129, 44341 Bouguenais Cedex, France
- Joël Lelong, Jean François Hamet - Laboratoire Transport Environnement (INRETS) -25, av. Mitterrand – Case 24 – 69675 Bron Cedex, France
- Nathalie Fürst - Centre d'Etudes sur les Réseaux, les Transports, l'Urbanisme et les constructions publiques (CERTU) - 9, rue Juliette Récamier, 69456 Lyon Cedex 06, France

SUMMARY

A new method for noise prediction on both aspects emission and propagation [1-2-3] has been produced in France under the coordination of the Technical Department for Transport Road and Bridges (Setra - France). The previous emission values were produced in 1980. The new model splits emission sound power per meter and per vehicle into an energetic sum of two components: one component induced by rolling noise, and other one by the engine noise. The propagation calculation has been also revised in order to correct the overestimation of the sound pressure level. The changes slightly modify the computation without any additional difficulties for its numerical implementation .

1. NOISE EMISSION

A. Methodology of production of emission values

The previous French method of noise emission calculation was based on experimental values issued from measurements performed in the 70's which do not take into account developments in vehicles and road technologies. The noise emission by vehicle has now to be linked to the engine aspect which depends on the engaged gear, the speed and acceleration and the slope of the road. The engine noise dominates for a low gear ratio. At higher gear ratio, the rolling noise becomes more important. It is supposed to depend only on the characteristics of the pavement and the speed. The following equation sums up the new approach to calculate the vehicle noise emission: L_{AMax} has to be seen as an energetic sum of the rolling noise and the engine noise [4, 5] :

$$L_{A\,max}(V,R,p,a) = L_{Rolling}(V,R) \oplus L_{Power\,Unit}(V,p,a) \quad (1)$$

where $L_{A\max}$ is the pass-by maximum sound pressure level (SPB) ;

[1] Currently in Laboratoire Régional de l'Est Parisien - Melun France

R is the category of pavement (see below) ;
p is the road slope ;
a is the traffic flow type (steady speed, acceleration, deceleration).
This assumption requires the necessity of splitting vehicles into two categories: light vehicles (below 3500 kg - LV), and heavy vehicles (HGV - 3500 kg and above). Motorcycles have not been taken into account because of the lack of information. Assuming the vehicle as a point source and using experimental results obtained from SPB method, we calculate in the methodological guide the sound power level per meter and per vehicle :

$$L_{W/m/veh} \approx L_{A\max} - 10\log V - 4{,}4 \qquad (2)$$

The power level per meter is thus given by :

$$L_{W/m}(j) \approx (L_{W/m/LV} + 10\log Q_{LV}) \oplus (L_{W/m/HGV} + 10\log Q_{HGV}) + R(j) \qquad (3)$$

where, *R(j)* is the value of the road spectrum standardised at 0 dB and A weighted : it is chosen between draining/non draining road surface for each third of octave j, Q_{veh} is the hourly flow rate of the category of vehicle . Equation (3) will be used in the propagation aspects.

B. Definition of pavement categories

Rolling components of traffic noise (LV and HGV) have been produced from many pass-by measurements collected in a database managed by the Regional Laboratory in Strasbourg. From the database information, statistic studies have showed that we can represent L_{Amax} obtained by SPB versus pavement families. These studies have led to a road classification into 3 categories R1 R2 R3 as shown in the following figure [6] :

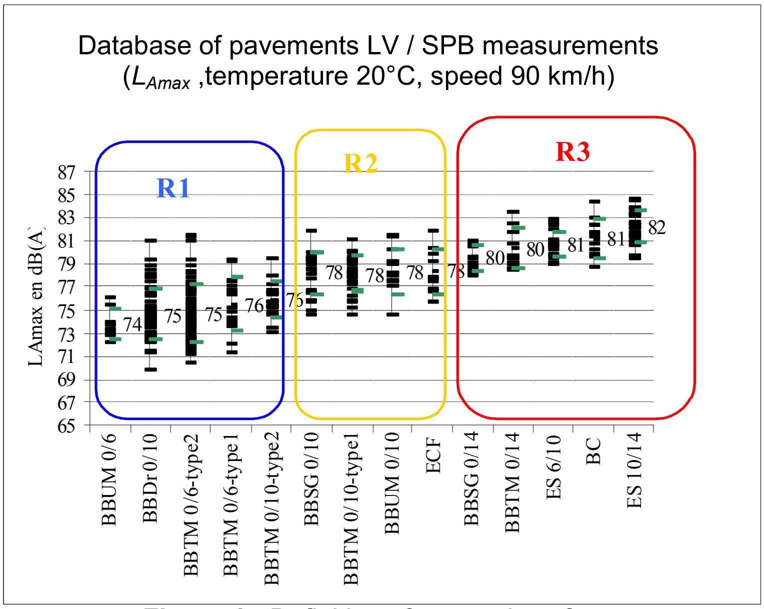

Figure 1 : Definition of categories of pavement

BBTM: Very thin asphalt concrete
BBUM: Ultra thin asphalt concrete

BBDr: Porous asphalt concrete
BBSG: Dense asphalt concrete
ECF: Cold mix
BC: Cement concrete
ES: Surface dressing

Each point corresponds to one section of measurement. The value of each bar is the average value of the pavement with its standard deviation in green. One can remark that the noisiest category corresponds to the pavements with large chipping sizes, whereas the least noisy category corresponds to the porous surfaces or pavements having small aggregate sizes. The drawback of the method is due to the fact that we have to follow the evolution of the market of new pavements that are not yet included in the database.

C. Rolling noise component

The rolling noise component $L_{r\_w/m}$ (sound power level per meter) is obtained by subtracting the power unit component of the vehicle from the global noise [7-8] . The underneath synoptic table summarizes the results, and shows the evolution of $L_{r\_w/m}$ for HGV and LV. These equations are representative of the emission for old pavements, at least 10 years of age. However, for a purpose of simplification, one assumes that the pavement has to be changed every 10 years :

		LV	HGV
Speed domain		20 km/h ≤ V ≤ 130 km/h	20 km/h ≤ V ≤ 100 km/h
Category of pavement	**R1**	53,4 + 21 log(V/90)	61,5 + 20 log(V/80)
	R2	55,4 + 20,1 log(V/90)	63,4 + 20 log(V/80)
	R3	57,5 + 21,4 log(V/90)	64,2 + 20 log(V/80)

Table 1 : Formula of the rolling noise component: " ten years old pavements "

As results are obtained from statistical studies, the 95% confidence interval has to be exhibited. The range of the values are between +/-2.5 dB(A) for HGV with a R3 pavement to +/- 3.4 dB(A) for LV with a R1 pavement.
Ageing is an important factor that contributes to the evolution of the noise emission of pavements. Noise emission values produced by the database are representative of 2 years old pavements. Studies have been made in order to find a time evolution of noise from 2 to 10 years. They showed that the variation seems to be linear with the age of the pavement, depending on the category of the pavement and the category of vehicle. In practical terms, the contribution of the ageing on the emission of noise is considered by adding a negative correction term to the previous noise relationships (see table 1).

D. Methodology adopted for computing the engine noise

The methodology supposed that the sound power level depends on the whole mechanical sources of the car. The L_{Amax} obtained according to CPB [8] method, is transformed into $L_{w/m}$ formula. Fourteen vehicles have been used in a large range of motorization [9-10]. The connection between the gear ratio and speed have been studied. Engine noise for stationary vehicles has also been measured. Finally, usual gear ratio representative of realistic situations have been recorded to understand the percentage of use of the gear box at steady speed [11]. The following table shows the L_{Amax} results obtained for a LV

V [km/h]	20 à 30	30 à 110	110 à 130
L_{engine}[dB(A)]	60.6	$66.3 + 12.0\log(V/90)$	$64.6 + 31.3\log(V/90)$

Table 2 : Engine component LV, speed stabilised, horizontal road. Values are given for L_{Amax} expression

In acceleration situation, the formula uses the results obtained by CPB in real conditions at full acceleration, assuming that the driver uses the optimal gear ratio and the best acceleration, seeking for the maximum engine torque. Experiments for horizontally road with deceleration, using engine break or pedal break were also studied. All the equations are similar to these given in table 2. The following figure summarizes the results.

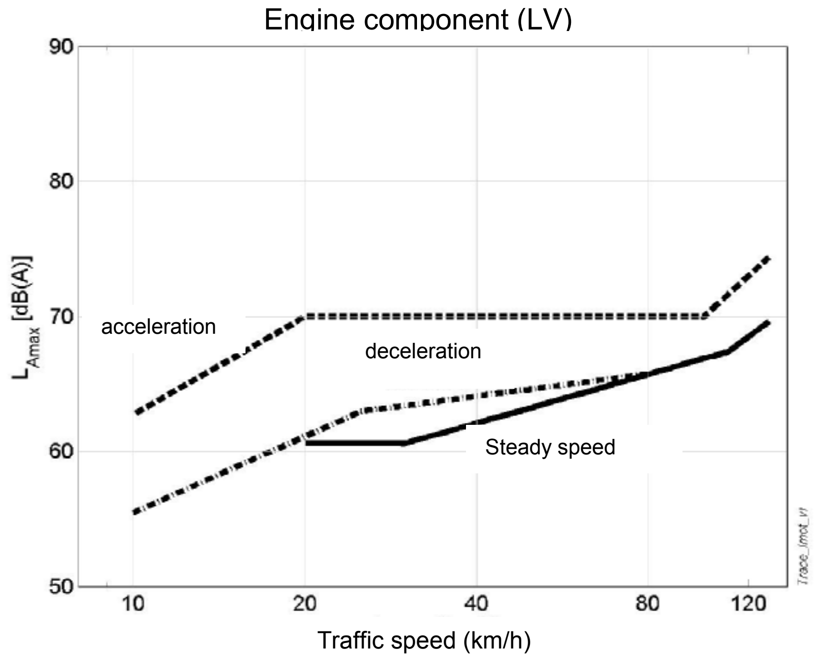

Figure 2 : Example of engine component LV Horizontal road

Notice that the velocity starts at 10 km/h to treat moving off section in acceleration/deceleration configurations. From this method, one can obtain the power emission per meter as the energetic sum of an unit contribution of each category of vehicle for which we add the corresponding contribution of the traffic flow and the value of the road spectrum (see equation (3)).

E. Conclusion for Emission

As a conclusion, the French method to predict noise emission presents a quite new approach to calculate noise emission. Consequences are not neutral because they induce a change in French regulation and noise management in the administration. They induce the necessity to follow the evolution of the low noise pavement market, in order to have always the latest equations in accordance with the new pavement.

The emission of motorcycles is not yet included, but studies are in progress on this topic.

2. NOISE PROPAGATION (NMPB 2008)

The former French traffic noise prediction method was published in 1996 [12], and a French standard proposed 5 years later. More recently, it has been chosen as the official interim noise prediction method for road to comply the European Directive on environmental Noise 2002/49/CE. The NMPB has been validated by comparison with several experimental campaigns including six sites with complex topography representative of real situations. The methodology adopted for the revision was the following :

- Proposition of corrections of the existing method (equations or procedure)
- Validation of the new equations by comparison to reference models (PE for instance)
- Implementation of the revised method and estimation of the improvements for the 6 experimental sites data.

A. Outline of the method

The method is based on the calculations of the long term sound pressure levels associated to the sound path between the source and the receiver. For each path, a computation is carried out for homogeneous and favourable (downward propagation) conditions. Each term is weighted by the probability of occurrence of these conditions in the direction considered and the energetic sum of these levels gives the long term sound level $L_{i,LT}$:

$$L_{i,LT} = 10\log[p_i 10^{0,1 \cdot L_{i,F}} + (1 - p_i)10^{0,1 \cdot L_{i,H}}] \quad (4)$$

where p_i is the probability of occurrence in downward conditions, Li_F and Li_H are respectively the sound level in downward-refracting conditions, and homogeneous conditions between the source S*i*, and the receiver R in a given third octave band. The energetic sum of the sound level contributions from all point sources and their potential image sources in a first step, and of the sound level in each third octave band in a second step, give the global long term sound level $L_{Aeq\ LT}$ used in French regulation. The ground is described through a mean ground plane between the source and the receiver as shown on the figure 3.

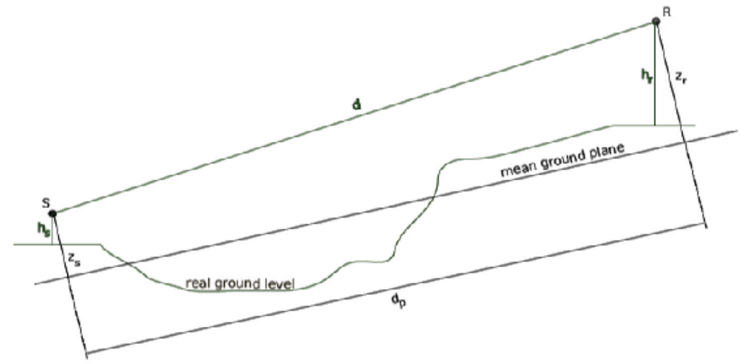

Figure 3 : Concept of mean ground plane

The sound attenuation between a point source Si of power L_{awi} and a receiver to be applied is given by:

$$A_{i,F/H} = A_{div} + A_{atm} + A_{boundary} \quad (5\text{-}1)$$

with

$$A_{boundary} = A_{embankment} + A_{diffraction} + A_{ground} \quad (5\text{-}2).$$

A_{div} is the geometrical spreading, A_{atm} the atmospheric absorption, and $A_{boundary}$ is the attenuation on the boundary which can either describe the effect of the ground (mean ground plane), of a noise barrier (including the specificity of low barriers), of buildings, of diffraction or of embankments.

Effect of diffraction and effect of ground or embankment are mutually exclusive : $A_{embankment}$ and A_{ground} vanish if diffraction exists in one third octave band and their effects are included in $A_{diffraction}$. If diffraction does not exist, $A_{embankment}$ and A_{ground} must be calculated and $A_{diffraction}$ equals to 0.

The ground absorption is calculated using a non dimensional parameter *G* (assimilated to a normalised flow resistivity) equals to 1 (absorbing ground) or 0 (reflecting ground). The computation methodology first consists in an estimation of a coefficient G_{path} which is an average of the characteristics of the ground. The following figure shows the methodology to calculate G_{path} :

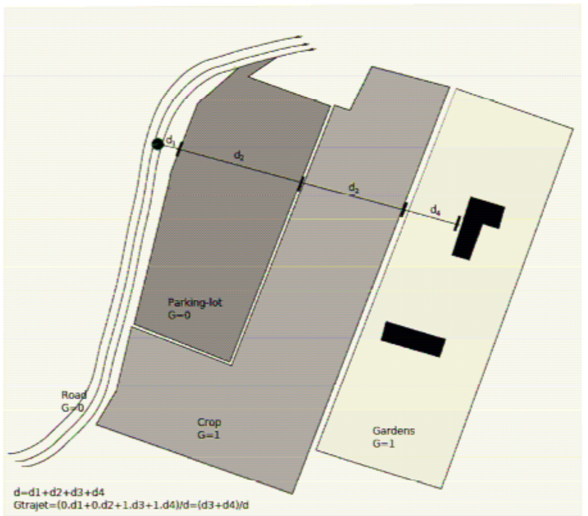

Figure 4 : Determination of the ground coefficient G_{path} in a propagation trajectory

$$G_{path} = \frac{0d_1 + 0d_2 + 1d_3 + 1d_4}{d_1 + d_2 + d_3 + d_4} = \frac{d_3 + d_4}{d_1 + d_2 + d_3 + d_4} \quad (6)$$

Next, its value is modulated depending on the distance between the receiver and the source: when source and receiver are close to each other, it is assumed that the reflection on the ground takes place on the road. So G'_{path} is introduced as follow :

$$\begin{cases} G'_{path} = \dfrac{d_p}{30(z_s + z_r)} G_{path} & if \quad d_p \le 30(z_s + z_r) \\ G'_{path} = G_{path} & otherwise \end{cases} \qquad (7)$$

where z_s and z_r are respectively the distance from the mean ground plane respectively of the source and the receiver (see figure 3).

B. Main changes between the old and the new method

Changes are the following:
- The source height is lower than the previous one (5 cm instead of 50 cm)
- Calculations are now performed in third octave bands instead of octave bands
- Two spectra of road noise emission are available: porous and non porous pavements

The limits of applicability of the method are the following:
- the maximum distance between source and receiver is 2000 m
- the upper limit between elementary source and receiver is maximum 10 times the range between the receiver and the road.

An important change comes from the computation of the ground effect in favourable condition. The method uses the same formula as in homogeneous condition after modification of heights to consider the effects of the sound ray curvatures and turbulence. These coefficients are added to the source and receiver heights with respect to mean ground plane. Besides, new minima values for A_{ground} are now proposed. Changes are in connection with the lowering of the source height.

C. Calculation in case of diffraction for NMPB2008

As for NMPB96, two mean ground planes are considered on both sides of point O in case of diffraction. However, for NMPB2008 the test of diffraction is now performed along the propagation path for each third octave band.

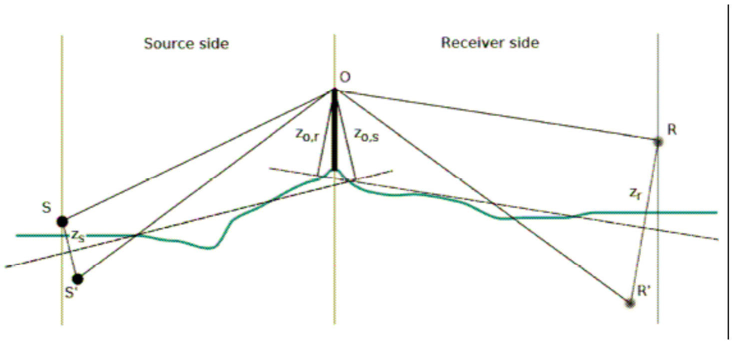

Figure 5 scheme of principle in case of diffraction

We can sum up the effects of the attenuation by the terms without diffraction for the path i. S being the source, R the receiver and O the diffraction point, F and H for homogeneous and favourable propagation conditions [14] .

In case of diffraction, the expression (5.1) for the sound attenuation between a source and a receiver becomes :

$$A_{i,F/H} = A_{div} + A_{atm} + A_{diffraction,F/H} \quad (8\text{-}1)$$

where

$$A_{diffraction,F/H} = \Delta_{diffraction\cdot F/H}(SR) + \Delta_{ground\cdot F/H}(SO) \cdot + \Delta_{ground\cdot\cdot F/H}(O,R) + \Delta_{Embankment\cdot}(SO) \quad (8\text{-}2)$$

Δ is the attenuation due to elementary diffraction for each 4 possible rays, including the source/receiver image towards the mean ground plane. $\Delta_{Embankment\cdot}(SO)$ is a new term that accounts for the effect of the embankment $\Delta_{diffraction\cdot F/H}(SR)$ is a term of pure diffraction. $\Delta_{ground\cdot F/H}(SO)$ is computed from the source to the diffraction point O and $\Delta_{ground\cdot F/H}(OR)$ from the diffraction point O to the receiver.

D. Comparison with the previous version

The NMPB2008 has been validated using a reference method (Propate Software developed by LCPC) and to a set of 6 experimental campaigns performed between 1996 and 1998 [15]. Figure 6 shows the deviation between calculated and measured attenuations for both old and new model. The accuracy of the method has been improved. Mean deviation changed from -1.7 dB(A) to -12 dB(A), and among the 310 measurements, only 32% have a deviation between measurement and computation higher than 2dB (50% for NMPB96). Although the shape of the distribution has been shifted and more centred around 0 dB(A), no significant improvements in the dispersion of measurement/calculation distribution has been noted.

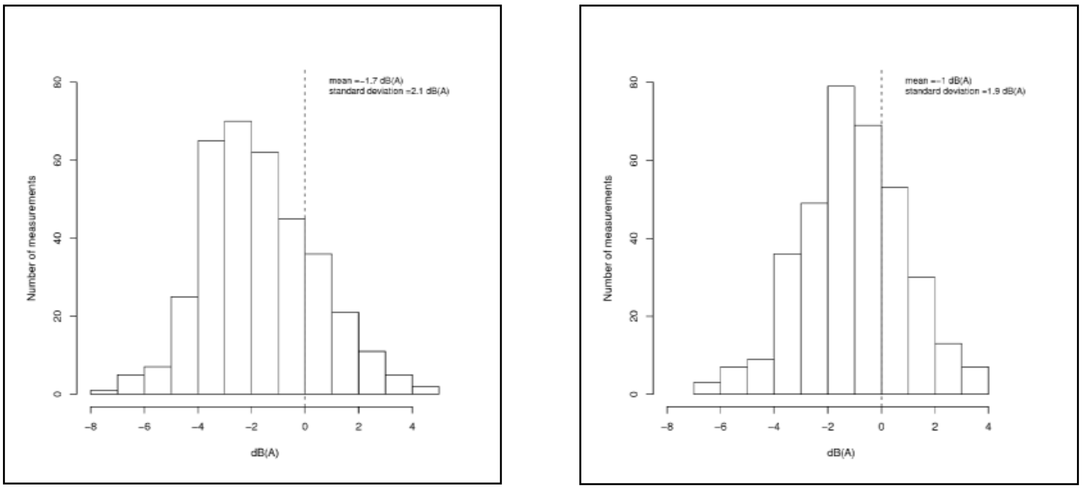

Figure 6 : Histogram of discrepancies between measured and calculated attenuation NMPB96 (left) and NMPB2008 (right)

E. CONCLUSION FOR PROPAGATION

The main change in the propagating aspect are related to downward refraction conditions. The new formula is similar to this representing homogeneous conditions including height corrections due to ray curvature and turbulence. Besides, embankment configuration with slope, and low barriers can now be treated. These improvements extend the field of application of the method. The comparison with the former one shows that the overestimations of the sound pressure levels are lowered. This is interesting with respect to the noise protection costs.

3. CONCLUSION

This new method for road traffic noise prediction is the result of many years of research involving French public laboratories. The results have been widely and rigorously validated by comparison with experimental data. Extensions of the method to railway and industrial noise are currently in progress . These extensions will provide a method that will be able to deal with different kind of noise source. English versions of both methods will be produced in 2009.

ACKNOWLEDGEMENTS

This research was funded by Setra (propagation and emission parts) and by Certu (emission part). Experimental campaigns have been carried out by the acousticians from the French network of Laboratoires Régionaux des Ponts et Chaussées. We thank the INRETS (for the emission aspects), and the CSTB (for the propagation aspects) for their active participation with Sétra to produce the new equations.

BIBLIOGRAPHY

1 Technical guide - Road noise prediction – 1 - Calculation of road traffic noise emission. Sétra 2009. Forthcoming.

2 Methodological guide - Road noise prediction – 2 - NMPB 2008 Noise propagation method including meteorological effects (NMPB 2008), Sétra 2009. forthcoming.

3 The revision of the French method for road traffic noise prediction G. Dutilleux, J. Defrance, B. Gauvreau and F. Besnard - Acoustics'08 - Paris - 2008

4 Vehicle noise emission of tyre/road and motor noise contribution – J. Lelong. In Internoise, Fort Lauderdale, Florida, USA, 1999

5 Bruit des trains routiers – Modélisation simplifiée à partir de mesures sur pistes d'essai – J.F. Hamet and V. Steimer. Technical Report LTE 2025, INRETS, 2000.

6 NF S 31-119 – Acoustique : Caractérisation in situ des qualités acoustiques des revêtements de chaussées – Mesurages acoustiques au passage, French Standard AFNOR, octobre 1993.

7 New vehicle noise emission for French traffic noise prediction Jean-François Hamet, Francis Besnard, Sonia Doisy, Joël Lelong, Emmanuel Le Duc, submitted to Applied Acoustics

8 NF S 31 119-2 – Acoustique : Caractérisation in situ des qualités acoustiques des revêtements de chaussée – Mesurages acoustiques au passage – Procédure "Véhicules Maîtrisés", Norme AFNOR, décembre 2000.

9 Emissions acoustiques des véhicules routiers –Campagnes de mesures 1997 – R. Michelet and J. Lelong, Technical Report MMA 9802b, INRETS, 1998.

10 Emissions acoustiques des véhicules routiers –Campagnes de mesures 1998 – R. Michelet and J. Lelong, Technical Report LTE 9922, INRETS, 1999.
11 M. André et al "etude expérimentale sur les utilisations réelles des véhicules (EUREV)", technical report n°48, INRETS 1987
12 Collective. NMPB-Routes-96, Bruit des infrastructures routières, méthode de calcul incluant les effets météorologiques. CERTU/SETRA/LCPC/CSTB, 1997
13 Jean-Francois Hamet, Marie-Agnes Pallas, David Gaulin, and Michel C. Berengier. Acoustic modelling of road vehicles for traffic noise prediction - determination fo the source heights. In 16 th International Congress on Acoustics, Seattle, USA, june 1998. ICA.
14 Defrance J. and Gabillet Y. A new analytical method for the calculation of outdoor noise propagation. Applied Acoustics, 57(2):109-127, 1999.
15 NMPB-Routes-2008:the revision of the French method for road traffic noise prediction G. Dutilleux, J. Defrance, D. Ecotière,B. Gauvreau, M. Bérengier, E. Le Duc, F. Besnard- submitted to Acta Acoustica, 11pages - 2009