Noise mapping for railway noise: assessment of NMPB method as implemented in different software, comparison with RMR method

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Abstract
The Directive 2002/49/CE on the Assessment and Management of Environmental Noise recommends the use of the interim Dutch method (RMR) [1] for railway noise mapping in countries that don't have their own official method. As in France the official method for railway noise mapping is the "Nouvelle Méthode de Prévision du Bruit" (NMPB) [2], a comparison of the NMPB and the RMR methods for railway noise has been developed.
Firstly, the implementation of NMPB and RMR methods in different computation models is analysed. The implementation of NMPB method is compared in Mithra, CadnaA and Immi models ; the implementation of RMR is compared in CadnaA and Immi.
Then, a comparison of the methods has been carried out, afterwards noise levels predicted in simplified situations have been compared and, at the end, more complicated situations have been modelled in order to compare the results of the simulations (RMR and NMPB) with measured data.

Résumé
La Directive 2002/49/CE sur l'évaluation et la gestion du Bruit dans l'environnement recommande l'utilisation provisoire de la méthode hollandaise (RMR) [1] pour les cartes de bruit ferroviaire dans les pays qui n'ont pas leur propre méthode officielle. En France, la méthode officielle pour les cartes de bruit ferroviaire étant la "Nouvelle méthode de prévision du bruit" (NMPB), une comparaison entre cette méthode et des méthodes RMR sur le bruit des chemins de fer a été développée.
Tout d'abord, les mises en œuvre de la NMPB et des méthodes RMR dans des modèles de calcul différents ont été analysées. La mise en œuvre de la méthode NMPB a été évaluée dans les modèles acoustiques Mithra, CadnaA et Immi ; la mise en œuvre de RMR dans CadnaA et Immi.
Puis une comparaison entre ces méthodes a été effectuée, à la suite de quoi des niveaux sonores calculés dans des situations simples ont été comparés, et, enfin, des situations plus compliquées ont été modélisées pour comparer les résultats des simulations (RMR et NMPB) avec des données mesurées.

The Directive 2002/49/CE recommends the use of the RMR Dutch method for railway noise mapping in countries that don't have their own official method. As in France, the official method for railway noise mapping is NMPB, that was used for a long time ago to predict the transportation noise, a comparison of the national French method (NMPB) and the interim Dutch method (RMR) for railway noise is needed.
On the other hand, the prediction softwares used to compute the noise maps include several methods. Then, a cross-validation is needed between softwares and methods to guarantee the accuracy of the predictions.
In the first paragraph, the implementation of NMPB method is compared in Mithra, CadnaA and IMMI softwares. And the implementation of RMR is compared in CadnaA and IMMI.
Then, a comparison of the NMPB and RMR methods is presented in paragraph 2. Afterwards, noise levels predicted in simplified situations have been compared. In the end, real situations have been modelled in order to compare the results of the simulations (RMR and NMPB) with measured data.

Comparison of NMPB method in Mithra and CadnaA softwares

The NMPB calculation method has been compared in Mithra and CadnaA softwares. The comparison has been carried out by means of results in punctual receivers and horizontal and vertical maps.
The obtained results are quite similar with both softwares, excepted for the night time period, where in some emission configurations, CadnaA overestimates the noise levels. It seems to be an error in the software development. In general, the results depend on the meteorological conditions and the ground absorption. The average difference in absolute value calculated in many receivers positioned at different distances from the source is presented figure 1 according the ground parameter G.

The higher the ground absorption, the higher the difference between models. This difference can reach 2,5 dB when ground is fully absorbent (G=1) which is not representative in practice.

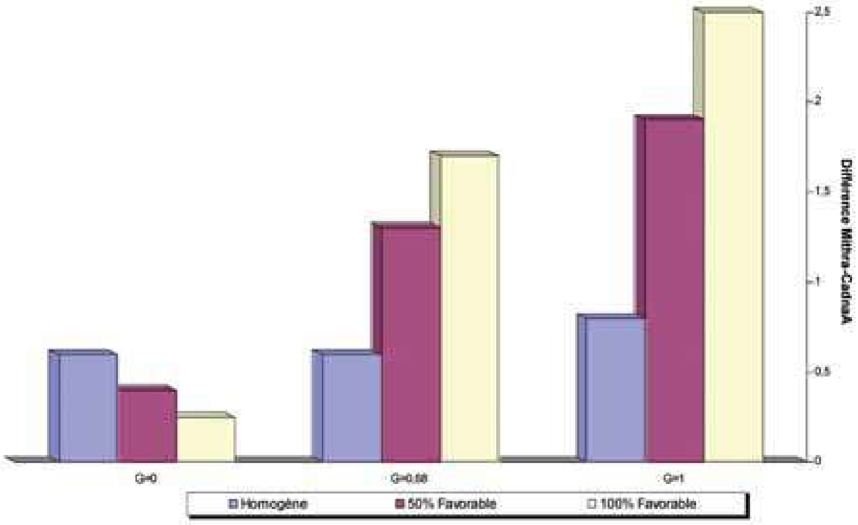

Fig. 1 : Noise levels difference in absolute values between Mithra and CadnaA

Différence des valeurs des niveaux de bruit entre Mithra et CadnaA

noise emission of similar trains. Then, the database of the SNCF emission values has been compared with the categories proposed in the RMR method.

Assignation of the SNCF trains emission to a train category of the RMR database

The SNCF trains emission database contains measured noise levels at the reference position (distance of 25m from the track centre and height of 3,5m above the rail). These values are compared with the results of the calculations carried out by means of acoustic softwares at the same position. The assignation is done to the most similar train in noise spectrum and overall value.

Theoretical comparison of NMPB-RMR methods

The difference in noise mapping when applying the French method NMPB or the Dutch method RMR has been also assessed. First of all, it is necessary to compare the

The figure 2 shows the measured noise spectrum of the TGV-Duplex train (double-decker high speed train) and the noise spectrum calculated with CadnaA using the “category 9” source and the noise spectrum calculated with Immi using “category 9B” source.

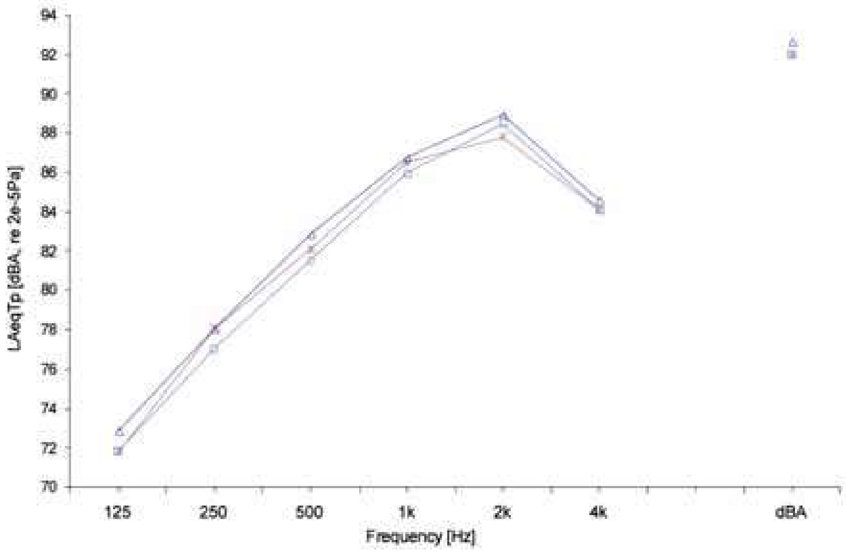

Fig. 2: Noise levels at the reference point (25 m from track centre and 3,5 meters above ground) measured for TGV-D train (+), and category 9 calculated with CadnaA (Δ) and category 9B calculated with Immi (o)

Niveaux de bruit au point de référence (25m du centre des voies, et 3.5m au dessus du terrain), mesurés pour un TGV-D (+), de catégorie 9, calculé avec CadnaA (Δ), et de catégorie 9B calculé avec Immi (o)

Sound pressure levels and spectra are very similar at 25m from the track. Even if the source models are not the same, mainly in terms of directivity, the isophones of the high speed train presented figure 3 turn out to be quite similar in both methods.

The same analysis has been carried out for freight train. It seems to be difficult to find a category in the RMR database which fit the measured data from the SNCF. As presented figure 4, the noise of the freight train measured by SNCF is 2 dB(A) noisier than the noise calculated with Immi or CadnaA using the “category 4” noise source.

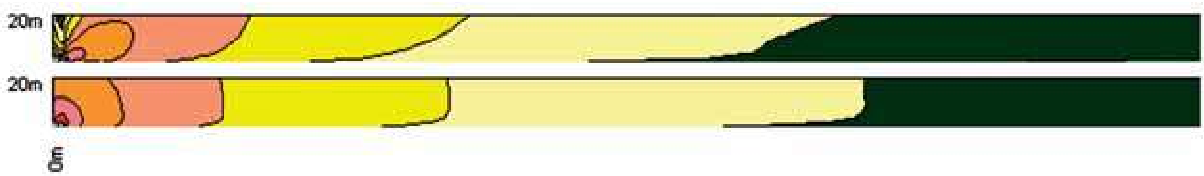

Fig. 3 : Noise levels for a high speed train at 300Km/h with absorptive ground and meteorological conditions 100% favourable. Above NMPB TGV-D, below RMR category 9 both calculated by means of CadnaA

Niveaux de bruit d’un Train à Grande vitesse à 300km/h, avec un sol absorbant et des conditions météorologiques 100% favorables. TGV-D avec la NMPB et RMR catégorie 9 calculés avec CadnaA

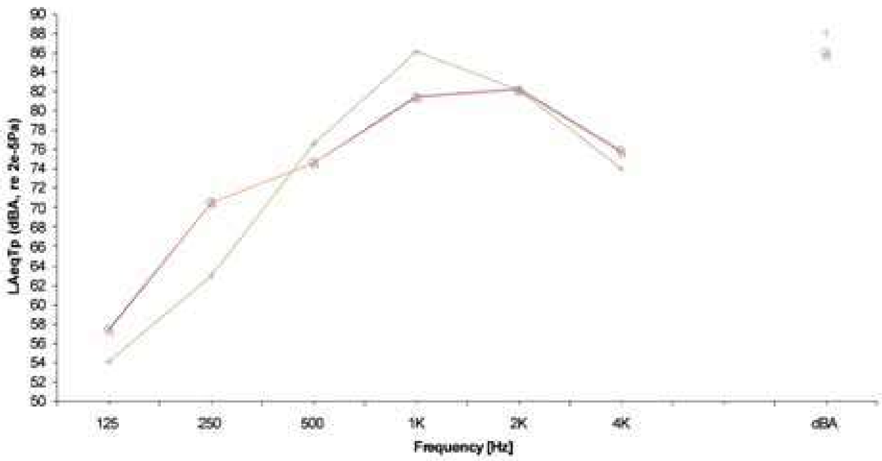

Fig. 4 : Noise levels at the reference point (25 m from track centre and 3, 5 meters above ground) measured for fret train (+), and RMR category 4 calculated with CadnaA (Δ) and RMR category 4 calculated with Immi (o)
Niveaux de bruit au point de référence (25m du centre des voies et 3.5m au dessus du niveaus du terrain) mesurés pour le train Fret (+), et sous RMR catégorie 4 pour CadnaA (Δ) et RMR catégorie 4 pour Immi (o)

Then, the difference in terms of sound pressure level and spectrum leads to a difference in the isophones curves as presented figure 5. In such a case, NMPB overestimates the levels compared to RMR.

Another fundamental difference between both methods is the number and the location (height) of the sources used to define the trains. For the high speed trains, four sources located at four heights (0,5 m, 2 m, 3 m and 4 m) are proposed in the Dutch method whereas the NMPB uses two sources allocated at 0 m and 0,8 m. This difference in the position can be significant when calculating the effect of a noise barrier as presented in the following example.

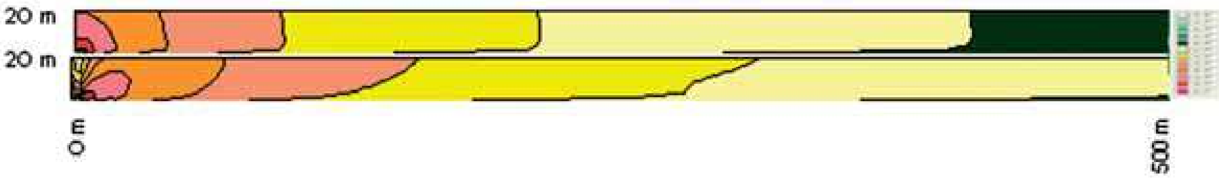

Fig. 5 : Noise levels for freight train at 100Km/h with absorptive ground and meteorological conditions 100% favourable. Above NMPB Fret train, below RMR category 4 both calculated by means of CadnaA
Niveau de bruit pour un train calculé à 100 km/h avec un terrain absorbant et des conditions météorologiques 100% favorables. Train fret avec la NMPB, et RMR catégorie 4 calculés avec CadnaA

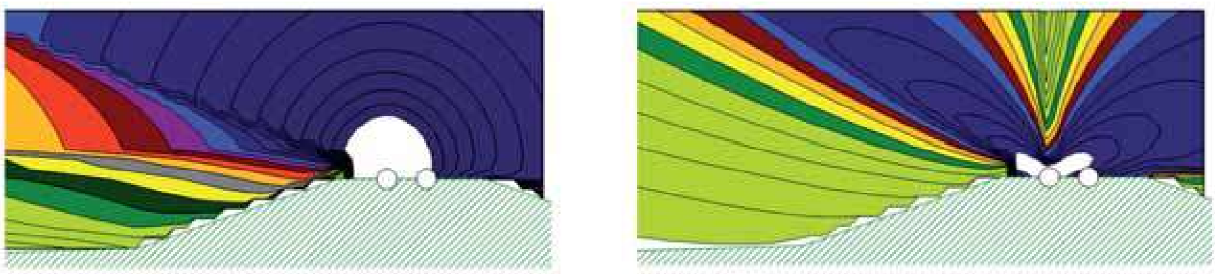

Fig. 6 : Difference in noise propagation of the high speed train noise behind a sound barrier (in black) with the RMR method (left) and the NMPB method (right) presented with the same colour scale
Différences de propagation du bruit pour un train à grande vitesse avec un écran (en noir) : Les méthodes RMR (à gauche) et NMPB (à droite) sont présentés sous la même échelle de couleurs

		Attenuation TGV-D (NMPB)	Attenuation Category 9 (RMR)
d = 7,5 m	h=2m	15,1	8,6
	h=3,5m	7,4	2
	h=10m	-0.4	0
d = 25 m	h=2m	13,5	4,8
	h=3,5m	13,6	4,7
	h=10m	6.2	0

Table 1. : Attenuations calculated for high speed trains passing-by behind a 2,5 meters high noise barrier located at a distance of 4 meters from the end rail (NMPB and RMR methods)
Atténuations calculées pour un passage de train à grande vitesse, avec un écran de 2,5 m de hauteur et à 4 m du bord du rail (méthodes NMPB et RMR)

Table 1 shows the attenuations calculated for high speed trains passing-by behind a 2.5 meters high noise barrier located at a distance of 4 meters from the end rail. Attenuations calculated with the RMR method are considerably lower due to the sources located on the roof of the train.

The figure 6 shows the corresponding isophones. The influence of the global directivity of the train source model is clearly depicted.

The same configuration with freight trains confirms the main role of the source model. As the noise sources of the freight trains are located near the rail, the results are very similar in both methods.

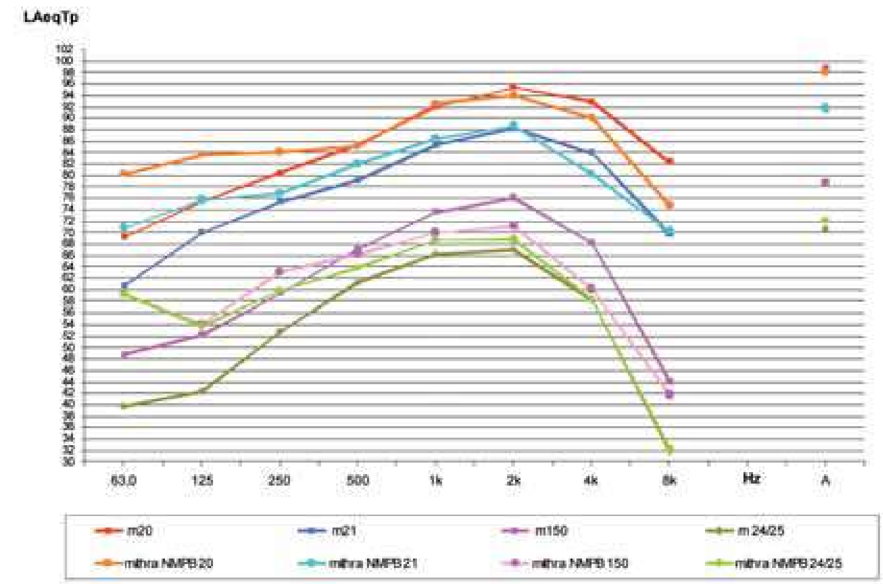

Fig. 7 : Comparison of measured noise spectrum during the passage of TGV-D and calculated noise spectrum with NMPB by means of Mithra software
Comparaison de spectre de la mesure de bruit durant le passage d'un TGV-D, calculé avec la NMPB et le logiciel Mithra.

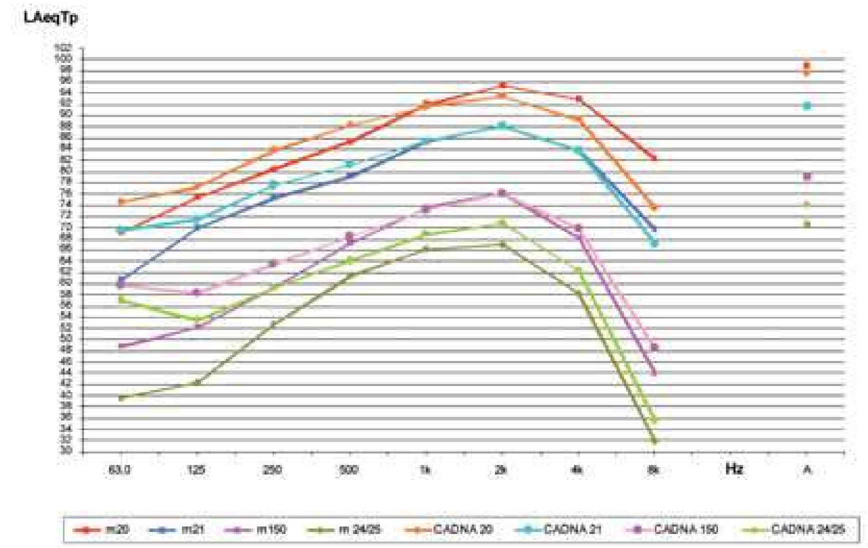

Fig. 8 : Comparison of measured noise spectrum during the passage of TGV-D and calculated noise spectrum with category 9 (RMR) by means of CadnaA software
Comparaison de spectre de la mesure de bruit ambiant durant le passage d'un TGV-D, calculé avec la catégorie 9 de RMR et le logiciel CadnaA

Difference in noise levels	Measures-NMPB MITHRA	Measures-NMPB CADNAA	Measures-RMR CADNAA
Receiver at 7,5m	0,8	1,2	1,4
Receiver at 25m	-0,3	-0,3	-0,1
Receiver at 150m	0,8	-0,7	-0,3
Receiver at 300m	-1,5	-2,5	-3,4

Table 2 : Difference of measured and calculated noise levels
Différences de niveaux de bruit entre mesure et calcul

Comparison of measured and calculated noise levels

After carrying out a theoretical comparison of the different calculation methods, a validation with real measurements was developed.

Pass-by noise measurements of TGV-Duplex were carried out with and without noise barriers. These measurements have been compared to the following calculations :

- Pass-by of a TGV-D calculated with the NMPB method in Mithra software
- Pass-by of a TGV-D calculated with the NMPB method in CadnaA software
- Pass-by of "category 9" calculated with RMR method in CadnaA software.

Real case 1: TGV-D without noise barrier

The measurement site is located in Pierrelatte in the Paris-Marseille high speed line.

The measurement site presents free field conditions. The ballasted track is equipped with UIC 60 rail and mono-block concrete sleepers. The train runs at 300 kph and is composed by 10 vehicles. Four receivers are located at four different distances from the track:

- *m 20* : receiver at 7,50 m from the centre of the track and 1,20 m above the rail.
- *m 21* : receiver at 25 m from the centre of the track and 3,50 m above the rail.
- *m 150* : receiver at 150 m from the centre of the track and 4 m above the rail.
- *m 24/25* : receiver at 300 m from the centre of the track and 4 m above the rail.

The test site has been modelled in Mithra and CadnaA softwares. The comparisons between measured noise levels and calculated noise levels are shown figure 7 and 8.

The comparison of the overall noise levels is summarized in table 2.

Considering overall noise levels at the four receivers, Mithra provides the most accurate results. Considering noise spectra, Mithra overestimates noise levels at low frequencies with a low impact on the dB(A) due to the A weighting.

Real case 2: TGV-D with noise barriers

The same comparison is carried out now with a noise barrier between noise source and receivers. Measurements are carried out on a test site located few kilometres on the north of the previous one. The railway track is also equipped with UIC 60 rail and bi-block concrete sleepers over ballast. The concrete noise barrier is 260 meters long, 2m high above the rail and is positioned at 4,3 meters from the rail end. Noise measurements where carried out with TGV-Duplex train at three different pass-by speeds: 200, 300 and 350 kph. Two receivers are located at a distance of 25 m and 100 m as presented figure 9.

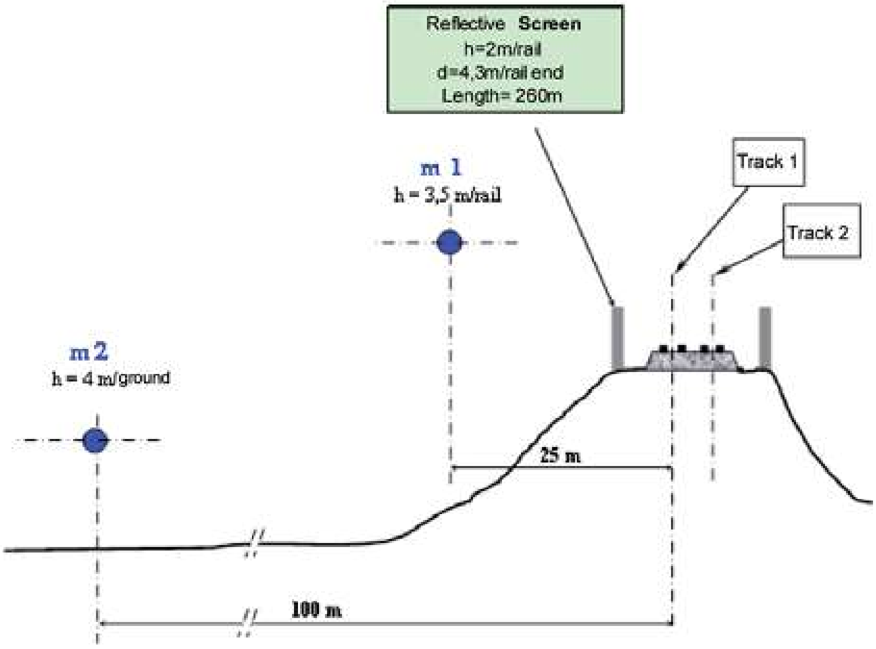

Fig. 9 : Measurement site schema
Représentation du site de mesures

The results compared for 3 running speeds confirm the influence of the source model. The results at 300 kph as they are representative, are presented in table 3.

High speed train	Measure-NMPB CADNAA	Measure-NMPB MITHRA	Measure-RMR CADNAA
Receiver at 25 m	13,3	12,8	3,6
Receiver at 100 m	15,4	14,9	8

Table 3 : Difference of measured and calculated noise levels at 300 kp/h
Différences de niveaux de bruit entre mesure et calcul, à 300 km/h

The noise source located 4m high in the RMR high speed train model leads to a more accurate prediction behind a noise barrier.

Conclusions

As in France, the official method for railway noise mapping is NMPB, a comparison of NMPB and the interim Dutch method (RMR) recommended by the Directive has been conducted. In the same time, Mithra, CadnaA and Immi softwares have been compared.
The comparison of the NMPB method in Mithra and CadnaA shows that the results are quite similar in very simple cases. The difference can reach 2.5 dB(A) depending on the meteorological conditions and the ground absorption.
The comparison of the both methods, NMPB and RMR, confirms the correspondence between the reference emission values from SNCF and train categories of the RMR method (in CadnaA and Immi softwares). For trains running at conventional speed, NMPB tends to overestimate the predicted sound pressure levels. The main difference concerns the simulation with high speed trains for which the source models are different in both methods. As high speed train is defined with noise sources located at from 0,5m to 4 m above the rail in the RMR method, the prediction behind a noise barrier is more accurate than with the NMPB. In free field conditions, both methods provide the same noise levels and after comparing with real measurements they are proved to be accurate.

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