inter.noise 2010
noise and sustainability
13-16 June 2010 . Lisbon . Portugal
www.internoise2010.org

ACCURACY AND PRECISION IN TRAFFIC NOISE PREDICTION

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Abstract
Traffic is the main source responsible for unacceptable exposure in densely populated communities. The first round of noise mapping and action planning according to 2002/49/EC yielded results with differences hard to be interpreted as real image of the noise climate in the MS. Based on a study financed by the German BAST (Federal Highway Research Institute), the influence of input data, calculation method and assessment procedures on the uncertainty of the final results of the calculation of road noise has been investigated. A ranking of the influencing physical phenomena shows that including effects of minor importance may waste a lot of effort and increase calculation times. The aim of the study was to understand the different approaches and to be able to take them into account in the intended revision of RLS-90.
In the following only some aspects can be described – the complete report will be published soon by BAST.

Keywords: Traffic noise, Noise prediction, Internoise 2010.

1 Introduction

With support from BAST (Federal Highway Research Institute) different methods used in Europe to calculate road traffic noise have been investigated to find the pros and cons of the applied strategies to include the important physical phenomena. The aim of the study was to understand the different approaches and to be able to take them into account in an intended revision of RLS-90.
In a first step the acoustical emission of a road in dependence of the influencing parameters should be compared. It is obvious that speed, road surface, lateral gradient and other parameters should show similar effects on sound emission independent from the country where the methodology is applied.

Many different methods are applied to calculate sound propagation. We can distinguish relatively simple engineering methods based on A-weighted levels or on octave bands on one side and more complex methods with narrow frequency bands, coherent superposition of different contributions from the same source, inclusion of Fresnel-Zone weighting of reflected sound and of meteorological effects in some cases. Examples for the first case are RLS-90, RVS 4.0, CRTN, NMPB and Nordic Prediction Method (NPM), while the more sophisticated models can be represented by NORD 2000, Harmonoise/Imagine or SonRoad.

In the following only some aspects and results of the study are presented – the complete report will soon be published by BAST.

2 Parameters influencing the Emission

The A-weighted sound pressure level caused by a piece of road was calculated in a distance of 10 m to find the dependency from speed and lateral road gradient. Even if this was the calculation of an immission, it reflects the wanted dependence from parameters including ground reflection and source geometry

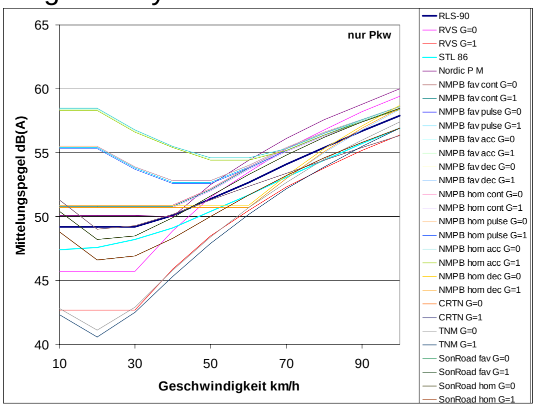

Figure 1**: The dependence of sound emission of a piece of road with passenger cars from speed calculated with different methods**

Figure 1 shows that the emission for passenger cars is similar and differs maximum 5 dB above 50 km/h.

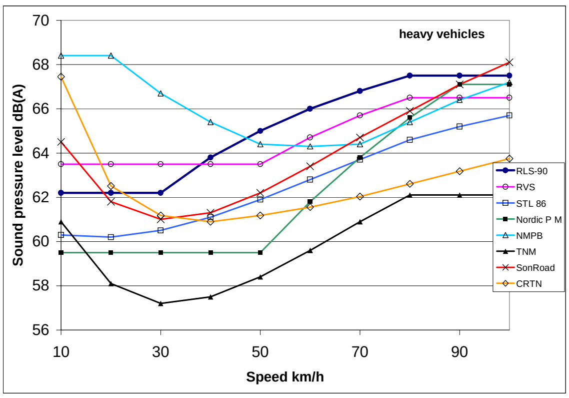

Figure 2**: The dependence of sound emission of a piece of road with trucks from speed calculated with different methods**

With trucks this interval is roughly 8 dB and therefore larger. One of the reasons is that some methodologies take different traffic flow conditions like accelerating, decelerating and others into account.

Extremely different are the methods to imply the lateral gradient and it is remarkable that it i staken into account in most cases as a single number correction even if the other calculations are based on narrow frequency bands.

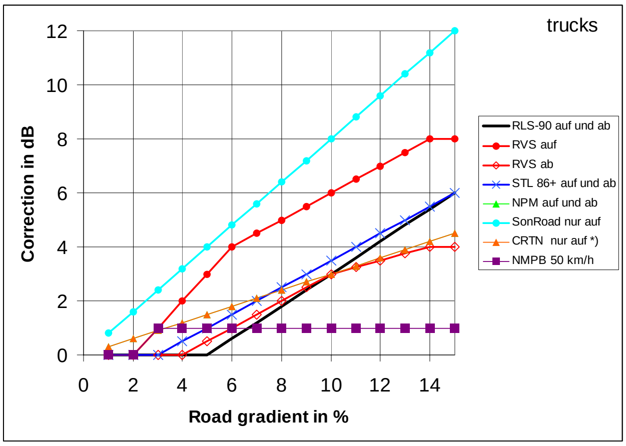

Figure 3**: The dependence of sound emission of a piece of road with trucks from lateral gradient of a road calculated with different methods**

With the existing RLS-90 reflections of first order are calculated according to the mirror image method. All higher order reflections are taken into account with a single number correction on the A-weighted level in cases where the road is located between closed facades. This correction for high order reflections between closed facades was investigated more thoroughly and derived analytically and with computer simulations. The result was a slight overestimation of the correction by the existing RLS-90 – in reality it will not exceed 2 dB. Taking this into account a real calculation up to high orders seems not to be necessary – it is recommended to revise the calculation of this influence but to keep the correction methodology.

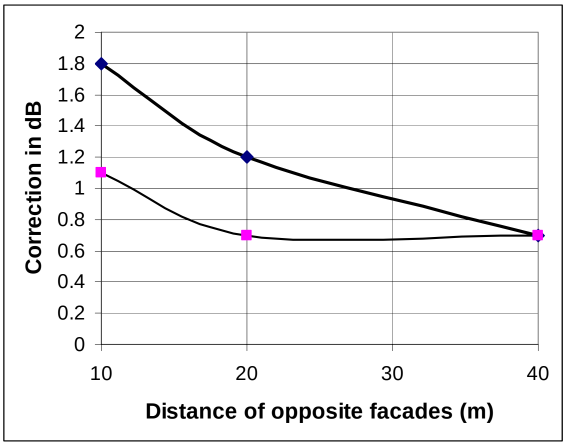

Figure 4**: Level increase by reflection of higher orders than 1 in dependence of distance between opposite facades (absorption coefficients 0.05 and 0.2)**

Newer methods show all the tendency to use narrow frequency bands – the broadest are 1/3 octave bands. But the increase in accuracy seems to be limited if influences like lateral slope or road surface are not also determined frequency dependent. Weighting these aspects of accuracy and the drawback of reduced transparency and traceability with narrow frequency bands the application of octave bands seems to be sufficient for a robust methodology used legal purposes.

It is further recommended to separate the emission in engine and tyre noise similar to other newer methods (e. g. SonRoad). This allows to relate the increase of emission with slope only to engine noise and the increase with speed to tyre noise.

3 Aspects of modelling

Single lane roads are modelled as line sources, as long as timely averaged levels shall be calculated. Different height are used in some models for tyres and engine. Roads with more than one lane are modelled with one line-source for each lane (NMPB), with two line-sources located on the axis of the outmost two lanes (RLS-90) or one single line-source 3,5 m behind the road curb opposite from the receiver (CRTN).

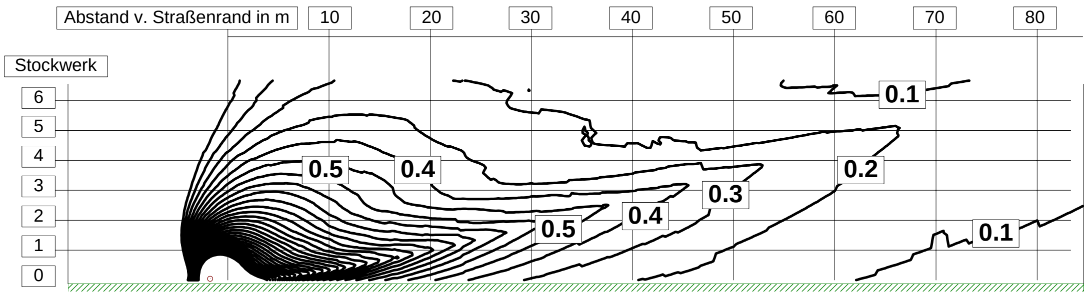

Figure 5**: Deviation of levels caused by the RLS-90 approximation (2 linesources) for a road with 8 lanes.**

To derive the error caused by the RLS-90 approximation the levels were calculated on a vertical grid once with each lane as a separate line-source and once with 2 line-sources according to RLS-90. The arithmetic differences of these levels are shown in figure 5. As it can be seen in the diagram the differences are smaller or equal to 0.5 dB everywhere in this case. With noise protection screens near the road these deviations may increase near the barrier edge up to 2 dB. But it should be taken into account that the detailed distribution of traffic on the different lanes is not known and may even vary in time. The RLS-90 approximation with 2 line-sources is therefore an acceptable approach in most cases. In complicated cases it is always possible to model each lane separately.

4 Calculation of sound propagation

To compare sound propagation according to different methodologies the sound level was calculated in varying distances from a piece of road with a receiver height of 3 m. The resulting level was normalized with the level resulting from free propagation with only geometrical attenuation. The resulting diagrams show the influence of ground and – in some cases – meteorology. Some of these normalized propagation curves for NMPB and for Harmonoise are shown in figures 6 and 7.

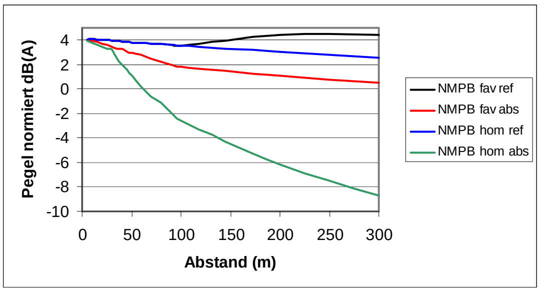

Figure 6**: Propagation (ground and meteo influence) with NMPB**

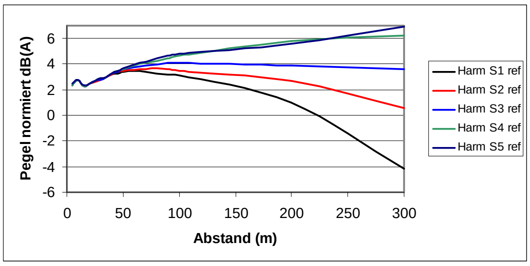

Figure 7**: Propagation (ground and meteo influence) with Harmonoise for reflecting ground and with 5 stability classes**

In both cases meteorology is an important input parameter, while RLS-90 is related to favorable propagation conditions.
Different methods are applied to take ground influence into account. While the simpler engineering models like ISO 9613-2, RLS-90 or RVS 4.0 produce an empirically based level increase with reflecting ground or attenuation with absorbing ground depending on the height of the sound ray, the newer methods like SonRoad, Harmonoise and NORD 2000 model the coherent superposition of direct ray and ground reflection including phase relations based on different length of these rays and on the impedance of the ground. To account for the extension of the reflecting surface element the concept of Fresnel-Zones is applied.

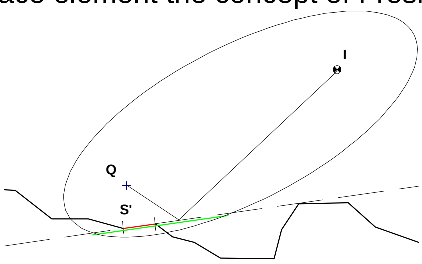

Figure 5**: Construction of a Fresnelzone to determine the contribution of a surface element S' to the reflected sound.**

The influence of these strategies on accuracy and performance of a the calculation were investigated by calculating sound levels from a road above an artificial wavy ground. Figure 6 shows the distribution of sound levels calculated with Fresnel-Zones and with coherent superposition of direct and reflected sound. It was found that these more complex concepts produce in some cases unexpected and difficult to verify patterns and need much more space of time in some cases.

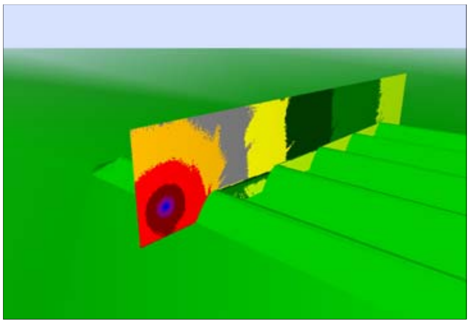

Figure 6**: Vertical grid with levels calculated with coherent superposition of direct and reflected sound.**

(The examples investigated have been calculated with the SonRoad and the Harmonoise method implemented in the software CadnaA).
Further investigations
The study includes the calculation of diffraction and reflection and the modelling and calculation with more complex constructions like screens with cantilevers, galleries and tunnel openings.

To investigate the general influence of meteorology the noise map of a complete city was calculated twice using the NMPB method. With these two cases the meteorological conditions of two different cities in France have been applied. The resulting difference map shows very small influences of meteorology far away from built up areas. This comparison proves that it is not necessary to take into account meteorological influences with methods that shall be used legally to check if limiting values are exceeded. The decrease of precision, transparency and performance will not be balanced by an adequate increase of accuracy.

Generally it is recommended in all decisions not to include more detailed and complex calculation strategies only because a better accuracy is assumed, but always to check an acceptable balance between accuracy, precision and transparency. Precision is important because the result of a calculation for the same scenario based on a legally implemented method undertaken by different experts should be the same. If unexpected results are found, it should be possible to trace the calculation with acceptable effort – this needs a requirement about transparency.
For the development of a revised RLS-90 it is recommended to follow the principle: “Not all what can be done must be done”.