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Accuracy and Precision in Traffic Noise Prediction

Dr. Wolfgang PROBST[a] and Bernd HUBER[b]

[a,b] DataKustik GmbH, Gewerbering 5, 86926 Greifenberg, GERMANY,
e-mail: wolfgang.probst@datakustik.de

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 (German Federal Highway Research Institute), the influence of input data, calculation method and assessment procedures on the uncertainty of the final results has been investigated. A ranking of the influencing physical phenomena shows that detailed inclusion of effects of minor importance may waste a lot of effort and – taking into account finite resources of time and money – increases the uncertainty of the final results. Some consequences and recommendations are discussed.

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1. INTRODUCTION

With support from BAST (German 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 /1/ was to understand the different approaches and to be able to take them into account in an intended revision of German calculation method 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.
For the calculation of 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 NORD 2000, Harmonoise/Imagine or SonRoad are examples for more sophisticated methods.

Based on a very stringent and legally fixed implementation of noise prediction and noise control in Germany, there is a lot of experience about the real needs in noise calculation. This experience shows that uncertainty – the deviation of a calculated noise level from the level that can theoretically be determined with an “ideal” measurement – is only one aspect to qualify a calculation method. Another and also very important property is the precision and transparency of such a methodology. Precision means that the levels calculated for the same problem by different experts should be identical. Transparency requires a clear and unambiguous description of the method. This is the only way to ensure that reasons for unexpected results can be detected and explained.
This is especially important with methodologies that are used to decide in legal issues. But from our experience we are sure that it can be formulated as a general requirement. In the following the different procedures are discussed with some examples. Some recommendations are given for a method with a well balancing of the 3 aspects accuracy, precision and transparency.

2. SOURCE DESCRIPTION – SOUND EMISSION

A comparison of different national standards for traffic noise prediction has been performed by calculating the sound pressure level of passenger cars and heavy vehicles separately – the receiver was in a distance of 10 m from a piece of road with similar parameters and the sound pressure level was calculated with varying speed. Figure 1 shows the dependency for passenger cars – with speeds of 50 km/h and larger the values are comparable with ± 2 dB. These differences are larger with heavy vehicles, but the application of these different methods on noise mapping project alternatively shows only little differences of the levels at the most exposed facades.

It can be doubted if the calculation based on A-weighted levels would be less accurate than the calculation of levels in frequency bands if typical roads with multilane traffic and the large variation of individual sources is taken into account.
A good compromise would be the calculation in octave bands - 1/3 octave bands blow up the data to be handled and the reports to be generated and reduce reproducibility of calculations too much.

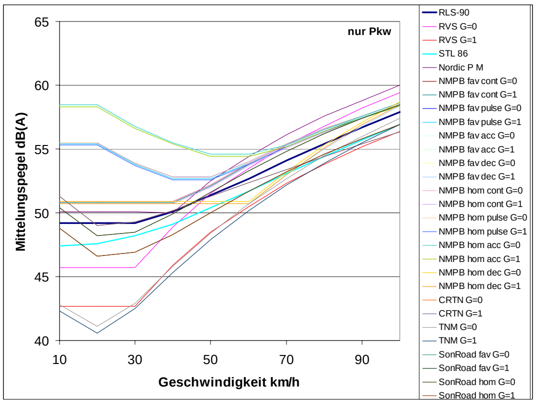

Figure 1. Sound emission of roads with different standards in dependence of speed for passenger cars

Rolling noise and engine noise can be described by two different source terms, because these mechanisms are influenced differently by road surfaces, road gradients and other system properties. The two sources can be attached to one single source line in a small height above the road surface. If different source height shall be used, two source lines to represent tyre and engine emission may be used. But with respect to the overall accuracy the adaption of these two source terms to different heights above road seems not to be necessary.

3. SOURCE DESCRIPTION – GEOMETRY

For multilane roads each lane can be modelled separately or – like it is done in the existing RLS-90 – one source line is attached to the axis of the 2 outer lanes.
Comparisons show, that the modelling of a multilane road with two line sources is adequate – if each lane is modelled separately, the levels are only slightly different from this proposed procedure. Figure 2 shows the level differences in a vertical grid across a 2 x 4 lane road, if each lane is modelled separately and if only 2 line-sources are used. These differences are so small that the 2-lane approximation can be justified in most cases. Generally the distribution of traffic flows across different lanes is not known anyway.

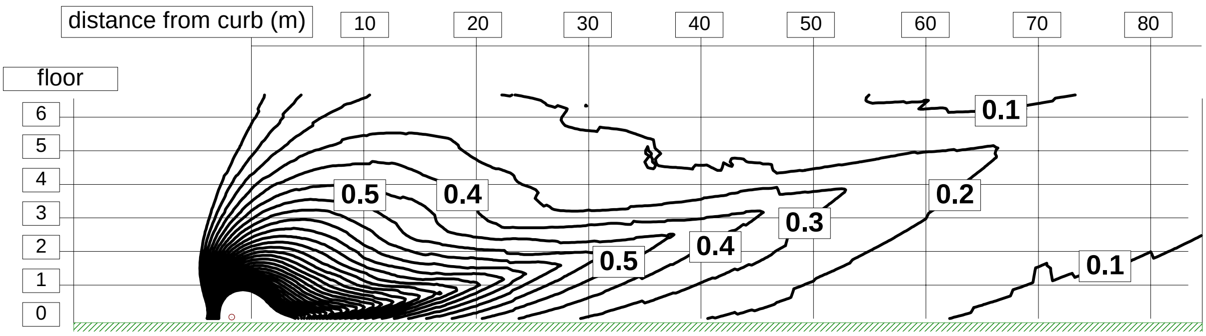

Figure 2. Difference in levels when the road is modeled once with 8 and once with 2 line sources.

4. SOUND PROPAGATION – FREEFIELD

Many national methods use a sound propagation calculation similar or even identical with ISO 9613-2. Appliers like consultants report good experiences with this standard, even if some little shortcomings have been detected – these should be improved with the next revision.

Ground effects

can be taken into account as more empirical corrections to be applied to the free field level (ISO 9613-2).

A much more physically oriented methodology is to regard the ground as a reflecting surface and to calculate the reflections according to the mirror image method. But this technique needs a spatial averaging, because contour lines, height points and generally triangulation techniques produce a tremendous amount of "little mirrors". This spatial averaging is provided by the concept of Fresnel Zones, where the contribution of each reflecting surface element to the reflected sound energy is dependent from its size relative to the wavelength and its orientation.

Some more sophisticated methods (Harmonoise, NORD2000 and SonRoad) apply coherent superposition of direct ray and ground reflection. This phase dependent superposition makes only sense if very narrow frequency bands are used (in SonRoad > 200 for each point to point calculation). Taking into account the complexity of real traffic sources this seems to be an overkill – the simulation of different cars with well defined source lines in fixed heights is a crude approximation that is accurate enough for energy concepts but fails for coherent superposition with interference effects.

Therefore two methods remain according to nowadays experience: to use empirical corrections equal or similar to ISO 9613-2 or to calculate ground reflections with the mirror image method based on octave bands energy related (incoherent superposition) and by applying a simplified Fresnel-Zone technique.

5. SOUND PROPAGATION – METEOROLOGY

Sound propagation is influenced by meteorological conditions like vertical temperature gradients and wind. The following methods are applied

- Meteorological effects not included (most traffic models like RLS-90,CRTN, RVS a. o.)
- Simple long term correction for different wind directions (ISO 9613-2)
- Two different meteorological conditions "favourable" and "homogene" (NMPB)
- 5 stability classes and wind direction and speed (Harmonoise)

The calculation of a noise map of a city with 80000 buildings applying different meteorological conditions has shown that the influence in agglomerations and other built up areas can be neglected. The influences are so small, that decisions about necessary measures will not be influenced.

6. RECOMMENDATIONS, OBSERVATIONS AND CONCLUSIONS

More than 20 years experience with consultancy in noise prediction problems and especially with "Hotline-Help" for users of prediction software shows that not only accuracy, but also precision and transparency of a method should be respected. Often it is intended to take into account more physical phenomena in a calculation method with the aim to improve accuracy.

But it is not realized that the loss in precision and transparency overcompensates this little improvement if second order effects are concerned. This is especially true if the number of necessary input data is extremely increased or if complex mathematical algorithms are implemented to describe some of these additional second order effects. A typical example is to demand for more detailed frequency spectra with narrower frequency bands if it is only based on the argument that this would be no problem for powerful computers. But this neglects the increased difficulty to find the reason for unexpected results and prohibits simple checks for single points with a spread sheet calculation.

It is obvious that all those achieving income from research and development tend to set priority on an improvement of accuracy and so to justify the need of further development. On the other side experts in administrations and consultancies applying the noise calculation software are interested in precision and transparency to ensure that the result of a calculation is repeatable and that plausibility checks can be performed.
It should be a general rule that an increase of accuracy that is used to justify more complexity and/or more input data should be validated by measurements. But such validations should be performed by other persons and not by those who proposed the method.

The necessary balance between these two abovementioned groups can be ensured by subjecting the calculation methodology to a standardization process. It forces the involved parties to describe the method clear and unambiguously and allows interested groups to contribute. The drafting period should be long enough to implement the method in software and to test it before final publication. The standard should include measures for quality control like test problems with published results, self-declaration sheets where the software developer has to declare what parts of the methodology he had implemented completely, approximately or even not.

Regarding the Member-States (MS) in Europe there is a curious situation. On one side they need a noise calculation method to check legal requirements. The comparison of calculated levels with legally fixed limiting values may decide about yes or no for planned projects and therefore precision and transparency must be ranked very high in such cases.

On the other side it is intended to use a harmonized calculation method for Noise Mapping and Action Planning in the frame of the Directive 2002/49/EC. There is no reason why we should not respect the same principles in both cases and so to replace later step by step the national methods by the harmonized method. Unfortunately EC went another way and the result can be seen: even 8 years after implementation of the directive there is no draft for a method fulfilling these requirements. The crossbar was adjusted very high and it was intended to produce a very accurate method, but neglecting the advantages of simplicity and clarity led to methods so complex that it was not possible to describe them unambiguously in a standard and to implement them in existing software platforms. One of the reasons may be that the experts deciding about these procedures are mainly members of the first group mentioned above – the development of the harmonized method is funded by the EC and therefore the application of existing and relative simple methods is not attractive.

This is what is meant with curious – the real requirements in Noise Mapping as a starting point for Action Plans don't need more sophisticated methods. If we take into account the measures that we can apply – low noise road surfaces, barriers, speed limits and traffic redistribution with less trucks near residential areas – then the noise calculation method has only negligible influence on the result if these effects are assessed. It is the secret of the

relevant EC organisations – DG Environment and others – why we go such complicated ways for an application like noise mapping with relative low requirements if we take into account the reason why we do all this work.
In fact we would come to the same package of noise reduction measures with all relevant national methods to calculate sound propagation. Much more important is how we distribute the representative receiver points to determine the exposure of the population – but here the mentioned administrations accepted extremely different methods equivalent to level differences up to 10 dB. In Germany the residents in each building have been distributed proportionally to all facades, while in most MS the level at the most exposed facade has been used to determine the noise exposure of all residents of the building.

From the authors point of view it can be stated that Directive 2002/49/EC is a very ambitious way to tackle the noise problems in Europe and over all Europe’s population may take their benefit from it. But the organizational treatment was a mess – tremendous lots of money have been wasted for developments that may be helpful to support the community of research institutes but have no influence on the general target: an effective noise reduction in the cities of Europe.

The dissatisfying situation – to have after years of funded development no result from Harmonoise/Imagine that is unambiguously described including quality assurance methods that could be implemented in existing software platforms – was covered by the new creation CNOSSOS. Moving into top gear the method to be applied was decided per acclamation of the same expert group – but the problems remain. To cope with the need of precision without a standardized and clear formulated description and quality assurance the idea of a single software realization was born. Again a lot of money shall be spent to reinvent something that has been developed since more than 20 years by free acting companies without any funding – to avoid the necessary standardization and quality assurance. It can only be recommended to compare existing centralized software solutions like TNM (USA) with the quality of free developed software (e.g. CadnaA, Immi or SoundPlan) in Europe: replacing the standardization and quality assurance procedure by a unique software implementation is a road with a dead end.

5. REFERENCES

[1] W. Probst, “Vergleich der Schallberechnungen nach den Richtlinien für den Lärmschutz an Straßen mit anderen Europäischen Verfahren”, Heft 1030 aus der Reihe „Forschung Straßenbau und Verkehrswesen“, Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2010
Title translated:
“Comparison of sound calculations according to the Guideline for Noise Protection at Roads with other European methodologies”