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Noise Mapping Techniques and their Ability to Support Planning and Mitigation

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According to the European Directive about Environmental Noise hundreds of noise mapping projects have been performed all over Europe. Experience has shown that many problems arise if these noise maps shall afterwards be used to develop noise reduction measures. In many cases recalculation in detail according to legal requirements produces results that are different from those obtained in the frame of strategic noise mapping. From this experience rules are developed that ensure the general applicability of the developed computer models. The methodologies applied should be accurate, precise and transparent to allow the assessment of possible reduction measures. Pros and cons of typical calculation strategies are presented and discussed. This investigation is based on road noise, but examples are also given related to railways, airports and industrial facilities.

1 Introduction

Although the European Directive on Environmental Noise recommends the use of certain standards for noise mapping purposes, different national standards are often used slightly adapted for this task. The same standards are also used for legal decisions, where more details are required. With these detailed recalculations, different results may occur. This especially accounts for standards that may be very accurate, but not precise and transparent. To overcome this situation, rules are needed for the application of computer models. Ideally, a harmonized procedure is used for the noise mapping as well as for legal decisions. In the following, possible techniques for such a model are analyzed regarding their accuracy, precision and transparency.

2 Techniques for the different steps of noise mapping

For noise mapping and noise calculation in general, three logical steps have to be considered: the source definition, followed by the propagation calculation and the immission evaluation. No matter which strategies are used – for example angle scanning or ray tracing for the propagation calculation – suitable techniques need to be applied for each of the 3 logical steps in order to obtain good results. In the following, terms like “good” and “better” will be used for the description of possible techniques used in the 3 steps. In this paper, these terms do not only account for accuracy, but for the combination of accuracy, precision and transparency.

2.1 Source definition

The description of the sources can range from a very basic and pragmatic one to rather complex ones, which are closer to physical reality and may therefore be more accurate. An important question is whether there is enough input data to justify complex source descriptions. This is important in order to keep the methods precise and transparent.

Roads are usually considered by defining emission lines and breaking them apart to finally use relevant point sources for the noise propagation calculation. Different techniques are possible when considering the actual number of lines which are used. One extreme solution is the use of just one emission line, like it’s done in CRTN; the other one is the use of one line per actual driving lane, like in NMPB. The RLS-90 can be found in between these solutions; here the two outermost lanes are considered with one emission line each. Investigations show that the calculation difference between the solutions from NMPB and RLS-90 are rather small. Considering that factors like the behavior of the drivers and their use of the different lanes are generally unknown, the gain of accuracy in NMPB compared to RLS-90 is negligible in this case, as can be seed in figure 1 [2]. Having in mind that the use of several lines with unknown lane usage of the drivers can be a source for different interpretation of data entry, a procedure using just two lanes might even be the better choice.

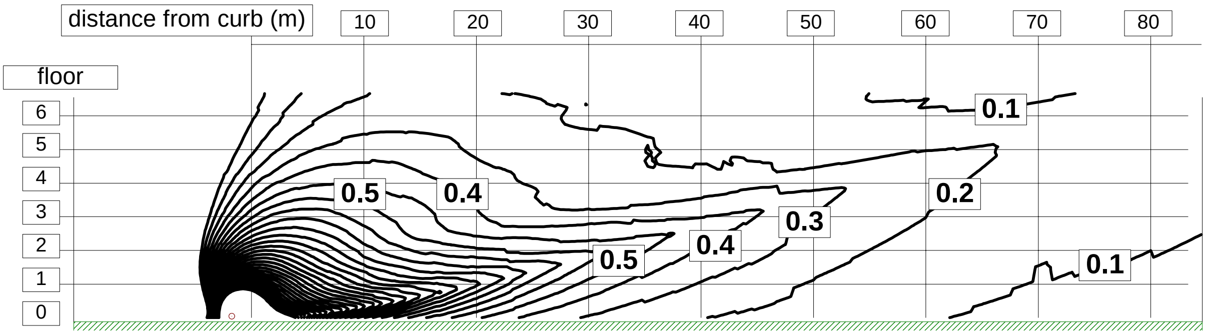

Figure 1: Difference in dB between an 8 lane road and its approximation (2 outer lanes), calculated with CadnaA; the difference is smaller than 0.5 dB [2]

Of course a certain amount of complexity often leads to better results. This does for example account for hourly based traffic data for roads or exact train schedules for railways instead of using average daily traffic counts. A standard where alternatively both inputs are possible is very helpful in this case. This way, the results will be usable when only daily traffic data is available, and improved if more exact data can be used. When using time tables for train data, the problem is that the input data is rather complex and must therefore be stored in a table for each cell of a table. With a suitable calculation program, updated schedules can be imported easily anyway, as long as the structure of the data remains the same. In CadnaA for example, an ASCII import can be used for importing schedules out of Excel sheets and using them for each individual part of the track without having to re-assign them manually; this has been applied for a railway project in London (ThamesLink) and is shown in principle in figure 2.

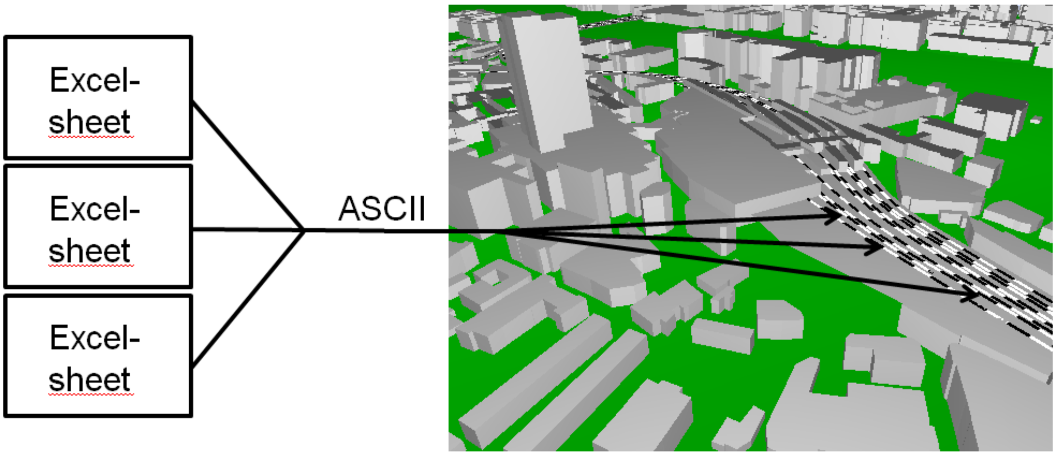

Figure 2: Principle for importing updated train schedules to the single railway elements in CadnaA

2.2 Propagation calculation

Noise propagation can either be calculated with physical approaches or engineering approaches. Due to calculation effort and consequently the general applicability, software packages for noise mapping purposes all use engineering methods [3]. Engineering methods may be based on calculating paths of rays or particles; in practice either ray-tracing or angle scanning methods are used (see figure 3).

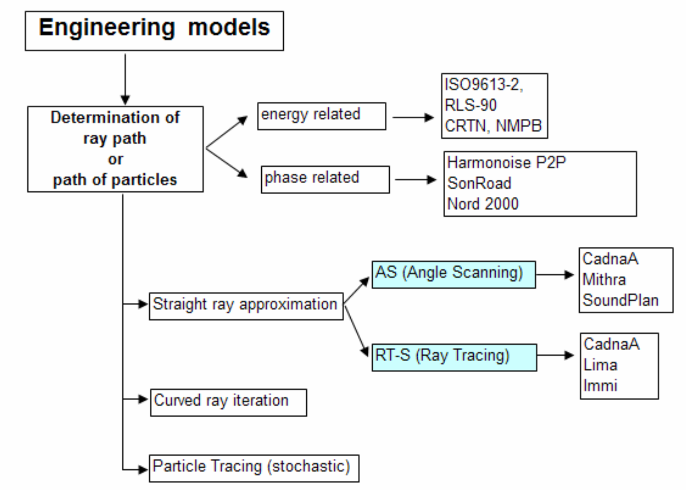

Figure 3: Overview over engineering methods for noise propagation calculation [3]

For these methods, different calculation strategies ranging from basic to complex are possible and are currently used with the implemented standards. The question is, which strategies and techniques could be suitable for harmonized methods in regard to accuracy, precision and transparency. In this paper, the focus is on whether and how to use reflections, meteorology and ground absorption.

The first example presented is about how to take housing next to a road into account. On the one hand, the reflection can be calculated ray based. With a high enough reflection order, this leads to quite accurate results; the drawback is a long calculation time, which can be a huge disadvantage when calculating large areas like cities. On the other hand, it is possible to simply add a penalty and not using mirror sources, like it’s done in the older standard CRTN. This is a fast and pragmatic way, but it gives inaccurate results especially when there are gaps in the housing. Alternatively, a compromise is possible, where reflection is just calculated for a very low order and a smaller penalty is added. With this technique, the calculation still is fairly fast, but gaps are considered.

A test case was conducted in the program CadnaA; the setup was based on the standard RLS-90. A road of 100m length was entered as well as housing with typical absorption coefficients in 5m distance along the road. Figure 4 shows the results. The left part shows the difference grid between a high reflection order (10) and the combination of 1 reflection and a penalty. The right part shows the difference grid between the high reflection order (10) and the calculation without reflections and just a penalty. As can be seen, the first case produces rather small differences (in 10m distance between -1 and 0 dB(A)) while saving a considerable amount of calculation time; the differences for the second case are much bigger (more than 4dB(A) in the same distance) without much more time save. Considering that multiple reflections may lead to a less precise calculation, as different reflection strategies may be used, the simpler approach with just one reflection order and a suitable penalty brings results that are transparent, precise and still accurate enough.

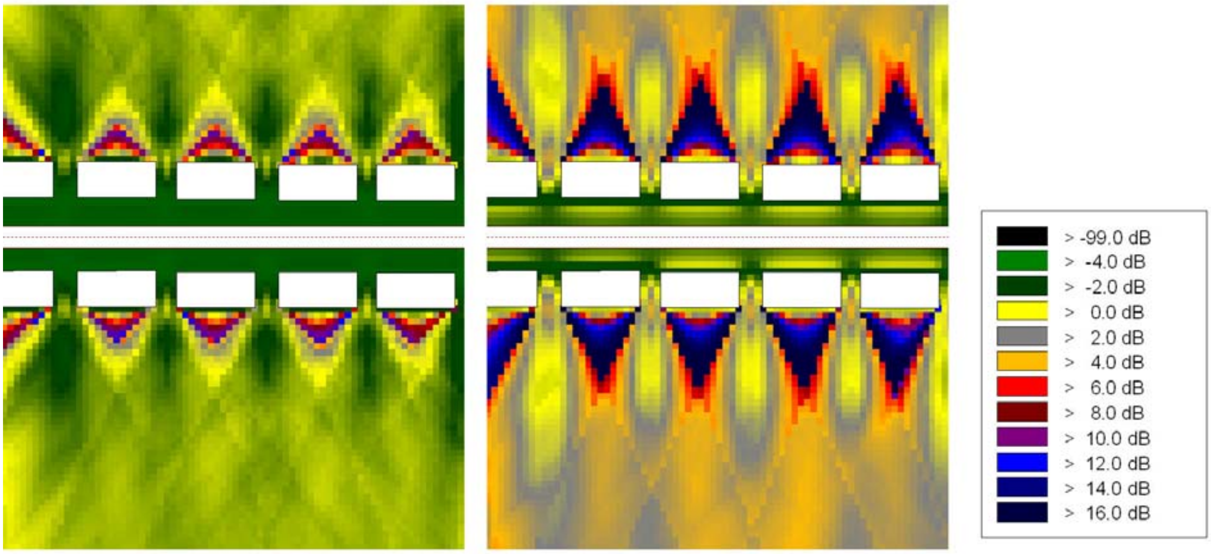

Figure 4: Difference between high-order reflection and reflection with 1 order and an additional penalty (left); difference between high-order reflection and 0 reflections with penalty (right)

Furthermore, the question arises if and how meteorology should be taken into account. Possible ways could be the use of wind statistics or more complex methods like CONCAWE compared to the downwind propagation in simpler standards. While generally meteorology can – especially for very large areas – have a large impact on the receiver level, this is not the case for cities (where noise mapping is used after all). Comparison calculations with a result displayed in figure 5 show, that the influence of meteorology for cities is very small [2]. So while the accuracy may increase a little bit, transparency decreases. Therefore in regard of the overall combination of precision, accuracy and transparency, which makes it possible to calculate the same results later when it comes to legal decisions, considering meteorology on a city-scale level does not improve the results.

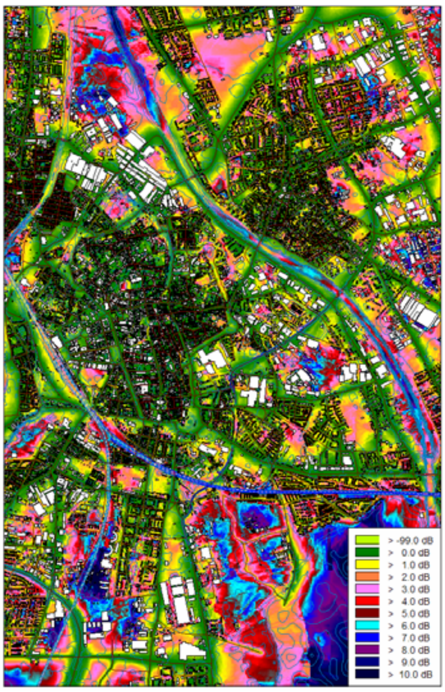

Figure 5: Level differences in a city (80000 buildings) between a calculation with favorable conditions and one with homogenous conditions according to NMPB [2]

The last examined question for propagation calculation is how to handle the ground. This can be done in quite a complex way, where ground reflections and direct sound are considered phase oriented. In ideal cases this leads to very accurate results, especially when a small amount of correlated sources are used. The main problem is that this complex calculation requires exact knowledge over the actual ground regarding its parameters like impedance, which can't always be provided. So in the worst case, different experts will interpret the input data differently and calculate different results; a technique like this would then make the standard less precise. That means that the quality of calculations in terms of accuracy, precision and transparency might be worse than in simpler ground models, which don't take the phase superposition into account. For the cases when the ground parameters are known though, a calculation program should be able to handle the more complex model as well in order to calculate with high accuracy.

2.3 Evaluation with immission values

A usual way of evaluating immission values is to compare them to limiting values after all calculations have been performed. These limiting values are set arbitrarily by the particular countries, but the calculations still must have been conducted with the highest possible combination of accuracy, transparency and precision. This is, because there may be legal consequences if the limiting values are exceeded.

A problem is that this comparison is not related to the number of people living in the houses. Buildings are treated the same way with no regards to the residents. One technique to overcome this situation is the highly-annoyed people concept [1]; another way is the hot spots analysis via noise scoring [4]. These are different strategies that actually take the number of people behind the facades into account. As different immission evaluation techniques don't influence the precision of calculation standards though, they are note examined in detail here.

3 Summary

Standards and the techniques being used need sufficient accuracy in order to create results which are close to physical reality. But only with additional precision these results can be created by different experts, and only with an adequate transparency it is viewable where level differences derive from. So a good standard will need all three factors – accuracy, precision and transparency - in order to be used effectively for noise mapping as well as for legal decisions. As a rule, a standard should be as simple as possible, except when complexity is needed to gain better results.

References

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