ICSV14
Cairns • Australia
9-12 July, 2007

14th International Congress on Sound & Vibration

BENCHMARK TESTS TO RANK SOFTWARE FOR NOISE PREDICTION

Wolfgang Probst

ACCON GmbH and DataKustik GmbH
D-86926 Greifenberg, Germany
Wolfgang.probst@datakustik.de

Abstract

Software for Noise Prediction is an invaluable tool to analyze complex situations. From detailed noise studies in industrial plants including calculations up to high reflection orders to large scale noise maps for hundreds of km^2 completely different subjects are covered by these software packages.
Unfortunately it is quite difficult for potential users like consultants and administrations to decide about pros and cons of different products.
User friendliness, speed of calculation and transparency are important properties beside the mainly published list of features. Methods based on the German standard DIN 45687 as well as more detailed test cases are presented to reveal these properties and to help decision makers to find a product best for their needs.

1. INTRODUCTION

Software packages usable for calculation and detailed analysis of complex industrial noise problems as well as for noise mapping purposes according to the Directive 2002/49/EC simulate the sound propagation from source to receivers by replacing the more or less complex wave field by geometric defined propagation rays. The shortcomings caused by this approximation are partially compensated with special techniques, but these are in some cases not standardized and therefore open for interpretation. For the potential user who wants to decide about the product best fitted to his needs it is difficult to get a more or less objective overview about the capabilities of all the available products on the market. Taking into account the complexity of the issue it is not astonishing that even people using a certain software package for many years are not aware of the uncertainties associated with the calculated results.

The German standard DIN 45687 was developed to improve this situation. The calculation guidelines or standards applied with a software package are regarded as the "truth", and any software bugs or even deviations caused by numeric approximations are treated as errors. Calculation methods must be described transparent and clear step by step that they can be included in the quality assurance system according to DIN 45687.

But even DIN 45687 is based on simple test cases and does not help to reveal the used approximation processes applied with a software product. Unfortunately nearly all researchers on the field of sound propagation focus on complex models like FFP (Fast Field Programme) or PE (Parabolic Equation) or try at least to include atmospheric propagation conditions and ground effects in geometric ray models – the improvement of the methods applicable for practical purposes and used all over the world for noise prediction is in many cases unattended and limited to an interchange of empiric equations between national methods.

In the following some of these problems are revealed and it is – necessarily with only some examples – shown how test cases can be constructed to get more insight into the inner procedures of a software package.

2. NUMERIC METHODOLOGIES

In the following only software packages are dealt with that can be used to calculate the noise levels in detail for practical industrial problems with complex sources and environments as well as for large scale noise mapping even in agglomerations. Complex methods solving the wave equation or simulating the sound propagation by discretising the propagation medium are not included, because they play a negligible role in practical applications.

The two different strategies Ray Tracing (RT) and Angle Scanning (AS) are used. It shall be mentioned that these names are used in the context of this paper – different expressions are used elsewhere.

Ray Tracing is used in most of the commercially available software packages. The possible ray paths between sources and receivers including direct rays and reflected rays are found by looping over all sources for each receiver – or vice versa – and constructed geometrically. Diffracting objects and other attenuating influences are taken into account by corrections of the calculated level contribution. The level at a receiver is the result of summing up the level contributions of all sources. Here are differences between the softwares – for large scale noise mapping calculation times may be unacceptable to include all sources, so only the relevant sources are included. But the strategies to decide about negligible sources are quite different and therefore cause quite different uncertainties. This is an important point to focus on if different packages are compared.

Angle Scanning works different – the 2D-angle of 360 degree around the receiver point where the level shall be calculated is partitioned in equal angle sectors – e.g. 100 sectors of 3,6 degree each – and one search ray in the axis of each sector starting from the receiver is used to find the relevant sources. Generally the point sources inside a sector are projected to the axis and the emission of the parts of extended sources like roads inside the sector is attached to the intersection with the axis.

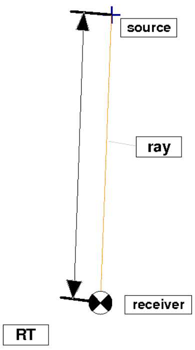

Figure 1. Calculation of level caused by one point source at the receiver with RT.

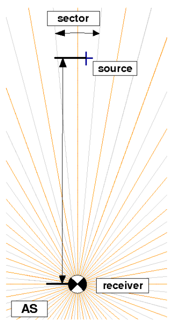

Figure 2. Calculation of level caused by one point source at the receiver with AS.

In a certain way RT is deterministic, AS a statistic approach. It shall only be mentioned that the AS approach can from principle also be used starting from the source and searching for receivers – but this technique was not used in well known and commercially offered packages.

Random Search (RS) is a further methodology to calculate noise based on ray techniques. The direction of the rays – or particles - sent out from each source are distributed randomly, and if such a ray intersects a control volume around the receiver, it is counted. The number of counts for each receiver volume is a measure of the sound energy and the basis to calculate the level. While in RT and AS the geometric spreading dependent on distance is included as a correction, it is replaced in RS by the relative number of counts for each receiver. It is obvious that the necessary dynamic or difference between maximal and minimal levels is an important criterium for the necessary calculation time to get a statistically significant number of counts at receivers with minimum exposure. These RS techniques are only of negligible importance in environmental noise prediction.

3. EVALUATION OF SOFTWARE PACKAGES - CRITERIA

3.1 User Friendliness

User friendliness is a property that is often undervalued. It is not only a “nice wrapping”, but an important issue with respect to avoiding errors (technically) and savings of time and money (commercially). DIN 45687 addresses this aspect – a clear structured graphical interface, easy usable different views including 3D presentations and the presentation of calculation rays even in 3D is invaluable to control a model and the calculation.

A short bill of important features:

- Graphic interface with windows that can be moved an modified in size (the project should always be visible)
- Direct call of all graphical features and back to the project with one click (otherwise control of inputs is to elaborate and will often not be done)
- Easy callable graphic presentation of calculation rays to selectable receivers (also necessary to facilitate control of projects)
- “Orthogonal programming” sounds technically, but is important with respect to simple and multiple use of modelled scenarios. The implementation of a new feature – e.g. a calculation method – should not influence any of the existing methods. It should further be possible to use the geometrical model including sources with different calculation methods. If the noise caused by a road is calculated with CRTN (UK), why not recalculating it with the German RLS-90 without input of a new RLS-90 road? This gives the program user the possibility to compare the results based on complete city models with minor adaptions.

There are a lot of program supported features that make much easier – but they are not seen at a first glance. It is necessary to ask for each product someone familiar with its use to work on the same little project or task to see how things are used and handled.

3.2 Calculation- and Simulation Strategies

As it was mentioned above, the calculation via ray paths between sources and receivers is an approximation of the real world where a wave field sweeps over the environment between sources and receivers. The following strategies are used and must be implemented correctly to get reliable results.

- **Correct subpartitioning of extended sources**
  If the noise caused by an extended source is calculated, the latter must be partitioned in small elements with an extension smaller than half (or another portion depending on the standard used) of the distance.

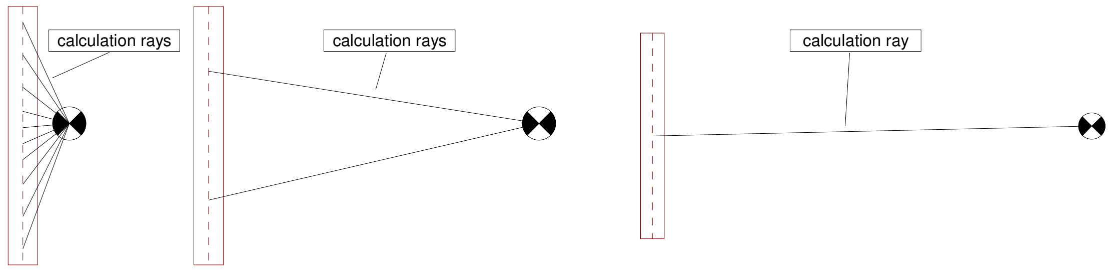

Figure 3. Dynamic partitioning of extended sources with RT – increasing number of calculation-rays with decreasing distance

With AS methods the angle sector must be configured small enough to fulfil these requirements.

- **Different propagation conditions must be taken into account**
  With automatic partitioning (RT) or constant angle steps (AS) the angles between adjacent calculation rays may be to large and the resolution may be to pour to calculate the exact energy contribution caused by the energy transfer through gaps between objects (e.g. buildings with gaps between them).
  The solution is to use
  - projection method with RT
  - small angle sectors with AS.

  The correct calculation can easily be controlled by using a configuration shown in figure 4.

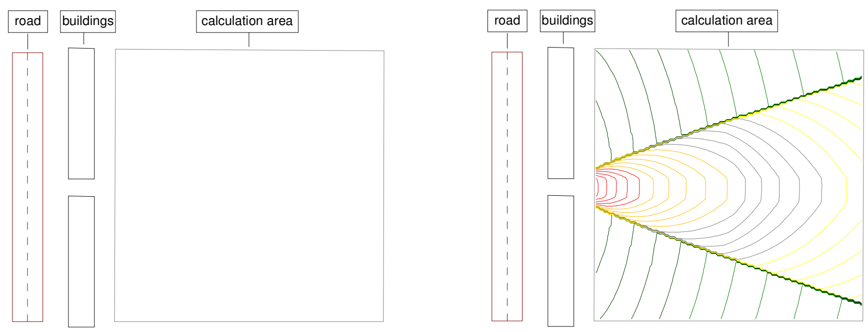

Figure 4. Left side scenario to calculate a map in an area screened by buildings with gap. Right side result of calculation using projection method (RT)

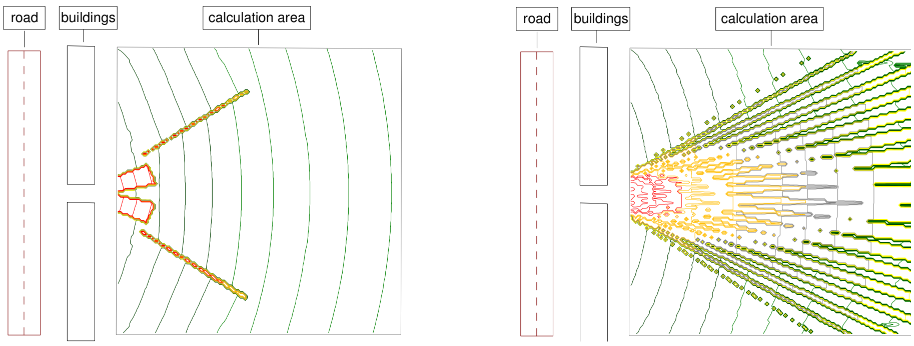

Figure 5. Left side calculation of lines of equal level with RT without projection method. Right side calculation of map with AS using 100 angle sectors for 360 degree.

Projection method is a two step procedure where in the first step the gap is projected to the extended source to get exactly the part contributing to the immission. In the second step the extension of each subpart is compared to the distance and – if it is to large – it may be partitioned further. The pattern of the lines of equal level are a sensitive tool to encounter wrong results. While figure 4 right shows the expected and correct result, it is obvious that the results of figure 5 are wrong. These strange patterns are not only a visual shortcoming – they indicate unphysical level jumps and therefore unacceptable deviations.

- **Reflections up to the declared order must be calculated correctly**
  Reflections are generally calculated using the mirror image method – this means that smooth reflecting surfaces are assumed and where this is not the case this solution is used as an approximation.

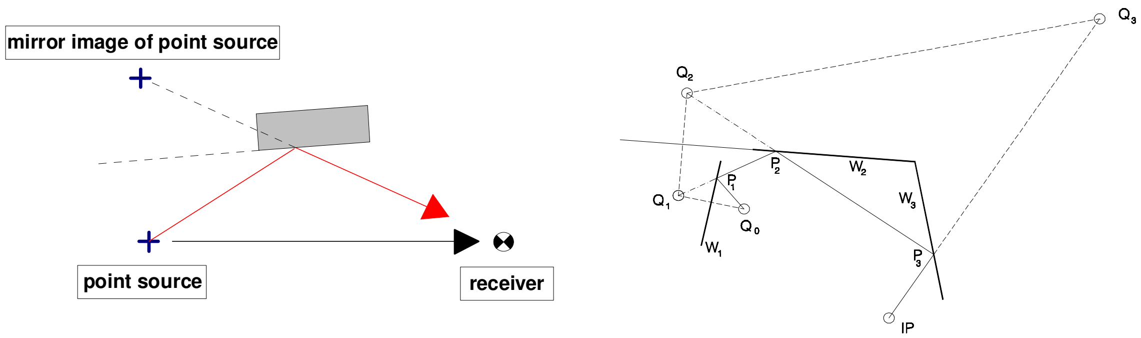

Figure 6. Construction of an image source to calculate reflections. Left side first order, right side third order reflection.

In cases of noise abatement in industry it is often necessary to calculate higher order reflections because the receiver position is screened and can only be reached by reflected rays. It is necessary that all possible rays are completely calculated – otherwise the result may be erroneous and there is no possibility to decide about the uncertainty characterizing the result.

Figure 7 shows a scenario that can be used to test if a software package is able to calculate reflections up to the 10th order correctly.

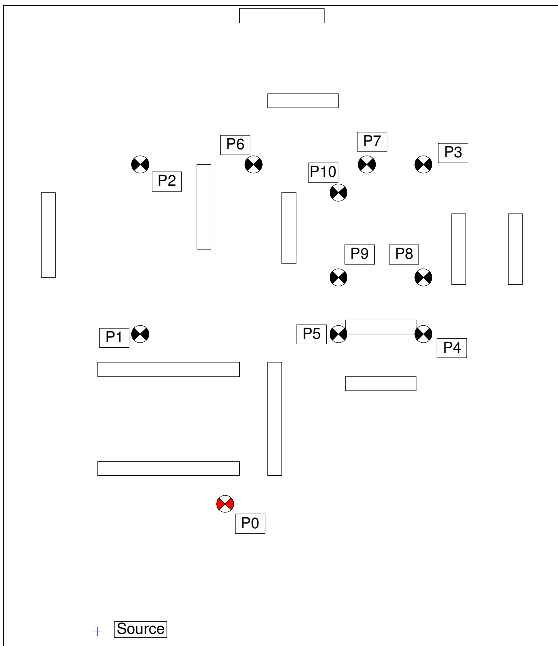

Figure 7a. Testcase with 12 reflecting objects

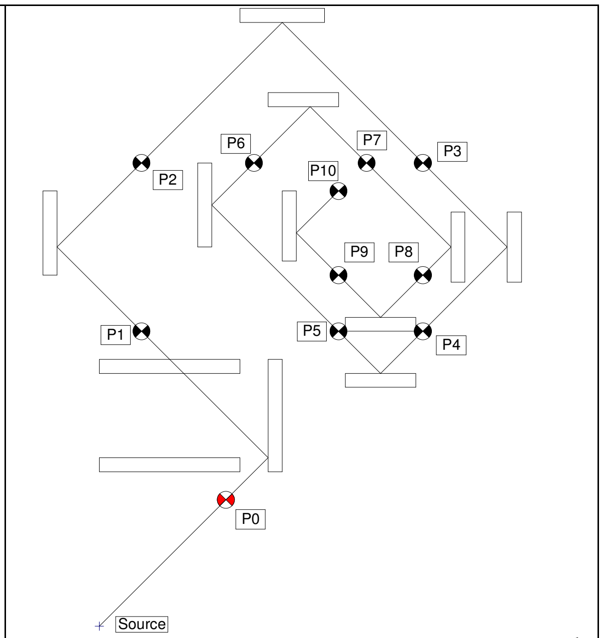

Figure 7b. Calculation with reflection up to 10th order

With the scenario shown in figure 7 the level is calculated for 10 receiver points. Starting with a calculation without reflections, the calculated reflection order is increased by one in each step. The results of each calculation are entered in columns of a table - table 1 is an example calculated with orders 1 up to 10. With each order more one receiver more is reached by the reflected sound – this must result in a level jump between the respective points with and without reflection. Table 1 shows that calculating with reflections up to 2nd order the level is decreased from P2 to P3 by 15 dB – because P3 cannot be reached by a 2nd order reflection.

Table 1. Result of a calculation with increasing reflection order

receiver	order of reflection calculated										
	0	1	2	3	4	5	6	7	8	9	10
P0	52.8	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
P1	28.3	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.4
P2	24.3	26.6	41.4	41.4	41.4	41.4	41.4	41.4	41.4	41.4	41.4
P3	22.5	24.8	26.4	37.4	37.4	37.5	37.5	37.6	37.6	37.6	37.6
P4	24.8	26.5	29.0	29.0	36.2	36.2	36.3	36.3	36.4	36.4	36.4
P5	26.1	26.7	26.7	27.5	28.5	35.1	35.1	35.1	35.1	35.1	35.1
P6	23.9	26.7	28.6	28.6	28.6	28.7	34.1	34.1	34.1	34.1	34.1
P7	23.0	27.3	27.3	27.8	27.8	28.0	28.1	33.2	33.2	33.2	34.7
P8	24.1	24.1	26.9	26.9	28.6	28.6	29.1	29.1	33.0	33.0	33.0
P9	25.1	27.0	27.0	27.0	27.0	27.2	27.2	27.4	27.4	32.0	32.0
P10	23.7	26.6	26.6	27.6	27.6	27.6	27.7	27.7	27.7	27.7	31.7

- The energy transferred by reflections into screened areas must be calculated correctly

To calculate the correct contribution of noise from extended sources like roads or railways radiated into screened areas, it is necessary to use the projection method even for the reflected sound.

Figure 8a. Scenario with piece of road, barrier and a reflecting building

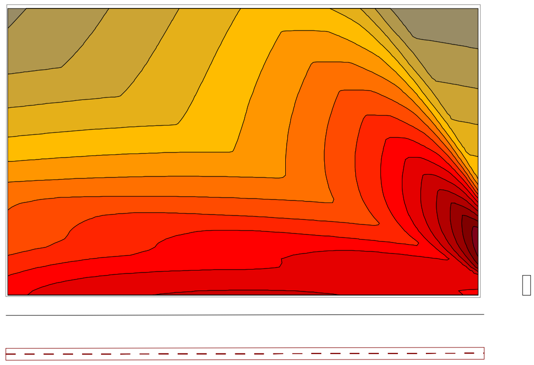

Figure 8b. Grid calculated with projection (RT)

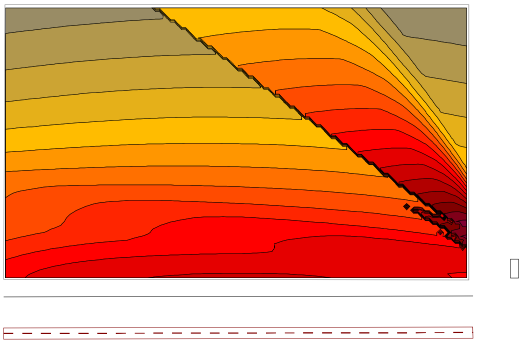

Figure 8c. Grid calculated without projection for reflected rays (RT)

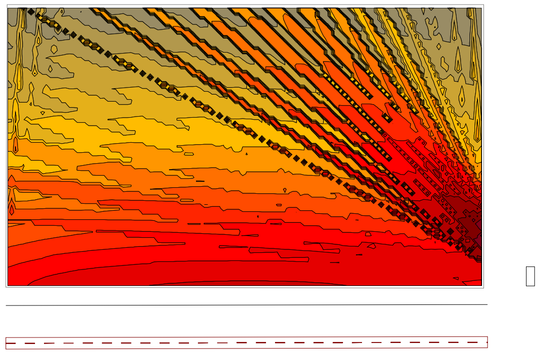

Figure 8d. Grid calculated with AS method using 100 angle sectors for 360 degree

These examples show that it is important to test the software used in the configuration that shall be used for the daily work. DIN 45687 provides a method that allows to calculate the confidence of grid calculations if acceleration techniques are used. Summing up it can be stated that a software for noise prediction is not a simple product that can be evaluated using the list of features published in sales literature. It is recommended to speak with the developers about the technique behind and to calculate some test cases to know about limitations and preferred application areas.

CONCLUSIONS

Noise levels are nowadays calculated in most cases with software programs on the basis of national and international standards and guidelines. Most of these models are based on an approximation of the propagating sound waves by straight rays. Extended sources like line- and area-sources are generally simulated and replaced by irregular grids of point sources. Effects like reflection, diffraction and combinations of them are taken into account differently. The potential user of such software is advised to calculate noise levels and noise maps with well defined and simple scenarios shown to test the correct inclusion of these effects that may influence the results considerably.

REFERENCES

[1] CadnaA – Software for the calculation and evaluation of environmental noise, Datakustik GmbH, D-86926 Greifenberg, Germany

[2] DIN 45687 Acoustics - Software products for the calculation of the sound propagation outdoors - Quality requirements and test conditions, 2006-05

[3] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise

[4] CRTN, Calculation of Road Traffic Noise, Department of Transport & Welsh Office, HMSO, London 1998

[5] RLS-90 Richtlinie für den Lärmschutz an Straßen, BM für Verkehr, Bonn 1990