



The 32nd International Congress and Exposition on Noise Control Engineering

Jeju International Convention Center, Seogwipo, Korea,

August 25-28, 2003

[N69] Software Strategies in Noise Mapping

Douglas Manvell

Brüel & Kjær Sound & Vibration Measurements A/S, Skodsborgvej 307, 2850 Nærum, Denmark

Email address: DMANVELL@BKSV.COM

Hartmunt Stapelfeldt

Stapelfeldt Ingenieurgesellschaft, Germany

ABSTRACT

Noise mapping is typically done for larger geographical areas over at least several square kilometres. This involves a large amount of data. At the same time, accurate calculation of noise levels may require detailed modelling of the environment, making the reduction of data difficult. Thus, environmental noise calculation software needs to analyse detailed acoustic situations as well as large-scale problems.

- This paper addresses issues that help acoustic modelling software efficiently handle this dichotomy, including:
- Producing consistent and plausible results according to regulations in the analysis of detailed geometry, such as complex barrier constellations and cantilever roofs
- The advantages of relative height models
- Fitting geometry onto terrain
- Applying variable grids, dynamic error margins, generalisation of geometry, etc. while analysing large models in order to enable fast calculation
- Using statistics for comparing results to check the influence of any simplification

KEYWORDS: noise mapping software, calculation, environmental noise

INTRODUCTION

According to the EU Environmental Noise Directive [1], noise maps will be produced for all large agglomerations. Conclusions drawn from noise maps might lead to significant investments and therefore a high standard of accuracy is mandatory. The size of the envisaged task (e.g. Fig. 1) demands an economic approach that takes accuracy into account. Data import and post-processing as well as data and result management will influence the economics. Accuracy is influenced by the quality of model data, handling of reflections and simplification strategies to speed up the calculation. Despite dealing with large-scale analysis, detailed geometry analysis is important for barrier effects. So balancing the two aspects is a challenge to software and users.

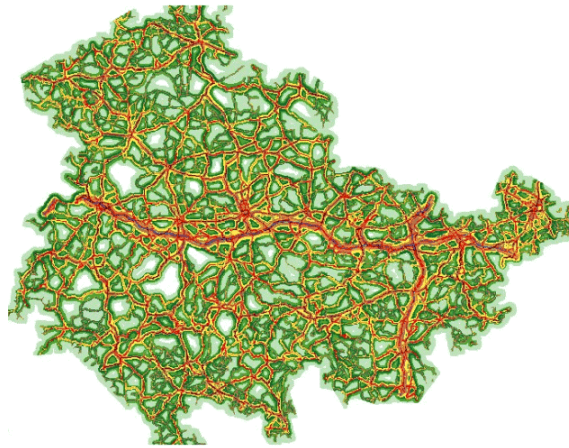


Fig 1. Noise map of Thuringen (18,000 km², roads and terrain)

Accurate models are not just essential next to the emitters, as conclusions about silent areas and facades are of interest as well. Simplifications, such as neglecting buildings far from main roads, will overestimate noise impact. Thus, why not assume free propagation, predict high noise levels and hope for attracting investments and subsidies? Instead, we should have the taxpayers' interests in mind and improve confidence in the map and in the authority by using realistic models that produce realistic results.

Calculation Methods and their Implementation

Accuracy depends on the calculation methods [2] as well as the input data. Each method seems to have individual pros and cons, for example:

- ISO 9613: Influence of low barrier ignores ground reflection
- RLM2 : No noise in the extension of or above the track

- NMPB : Ground reflection combined with:
 - a) barriers next to source/receiver
 - b) skyscrapers on hillside

Software developers have to interpret these methods. Typically, complex geometry has to be reduced to a simple geometrical situation described in the method. This may cause different results in different software packages. As software developers have to offer a tool which works on detailed as well as large models, various options are provided. The user thus needs documentation and training to make adequate use of them. For noise mapping, a desired accuracy needs to be defined and by applying statistical tools the user should prove that his settings for the calculation were adequate.

In cases where there are no GIS data available, it is tempting to use attenuation areas (e.g. instead of individual buildings). However determining attenuation rates (e.g. based on “catalogue model situations”) is a lengthy and ambiguous process with undefined result accuracy. It is often more economic to invest in setting up a proper GIS system first. Although widely available, the degree of detail of GIS data is a challenge for the noise mapping software. Automatic simplification can be applied depending on the task. It is fast and it gives the chance to document its influence on accuracy of results.

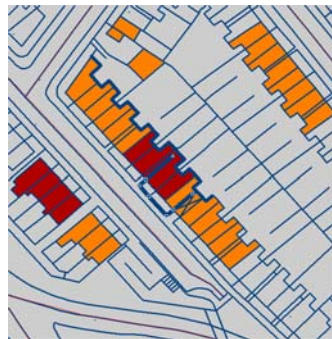


Fig. 3. Concatenating to polygon objects for proper screening & noise exposure statistics

A wide range of 2-D and 3-D GIS data formats are in use and specific converters are needed to import them into the acoustic model. As these data have not been set up for an acoustic simulation, post-processing is needed, such as:

- Check multiple geometry, e.g. due to part of a road being digitised forwards and backwards
- Define height of 2-D objects relative to terrain or other structures
- Redefine start of a building polygon to match with height definition
- Automatically re-segment lines (e.g. roads) to fit to the terrain
- Concatenate singular vertexes to polygon objects to allow proper screening and

noise exposure statistics (Fig. 3)

- Allocating attribute information by linking objects to database entities or supporting logical or geometric pre-selection

During recent years laser scan data collected from aircraft have become available. This can be used to automatically generate a 3-d model or can be merged with existing 2-D GIS data to produce high quality 3-D terrain and building models. In a pilot project (City of Bonn) terrain accuracy was within 30 cm (Fig. 4).

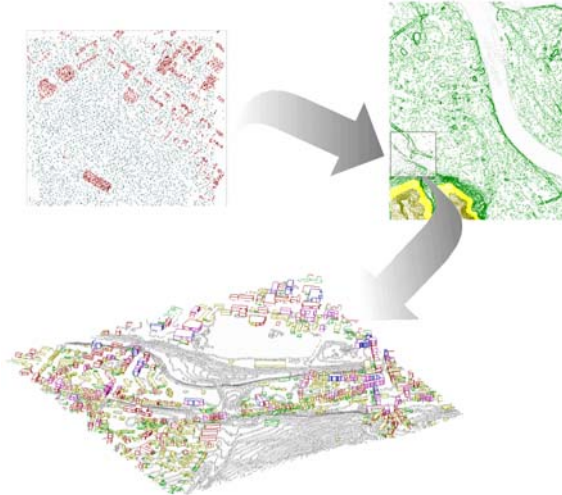


Fig. 4. Merging laser scan data with 2-D GIS data to produce a high quality 3-D model

The advantages of relative height models are discussed in [3].

TOOLS FOR FAST CALCULATION OF LARGE MODELS

To optimise calculation speed, all objects of the relevant model area need to be kept in memory. This puts demands on the software to rapidly recognize all the relevant obstacles between receptor and emitter. One common technique to reduce the problem is to define a fetching radius within which emitters next to a receptor position are searched. Guidelines for such a radius, depending on the maximum power of any individual source, are of little help as sources might occur in clusters. Generally, radii of 2000 - 3000 m are chosen, but quality checks should be applied. To ensure steady results at the edges of any “calculation tile” the relevant model area should exceed the result area by this fetching radius. For calculation areas of 1 km² and a radius of 2000 m, 25 km² of model area is required – for Bonn (Fig. 9) this means about 212,000 obstacles. With a radius of 3,000 m and hilly terrain, such as in Hong Kong, up to 1,000,000 objects need to be handled within the calculation. This will require machines with 256 MB memory.

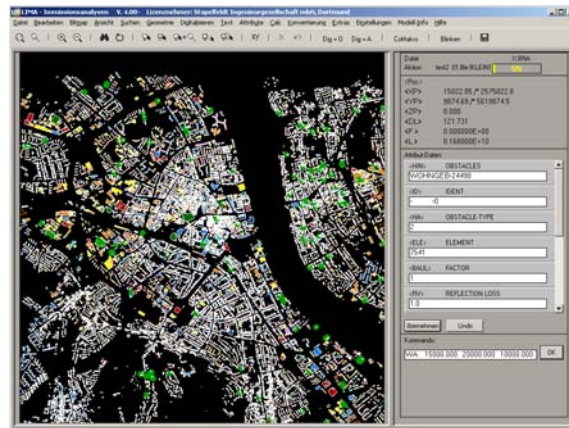


Fig 9. Noise map of the city of Bonn, Germany

To reduce calculation, irrelevant emitters within the fetching radius can be neglected. However, simply neglecting “small” emitters fails in several cases, e.g. when the bend of a highway junction is entered in segments of a few metres due to CAD planning tools. Therefore, the potential influence on the result level caused by all neglected emitters needs to be catered for. The user may define an acceptable maximal total error margin (e.g. the 1 dB value in Fig 10 that optimises result quality with calculation speed).

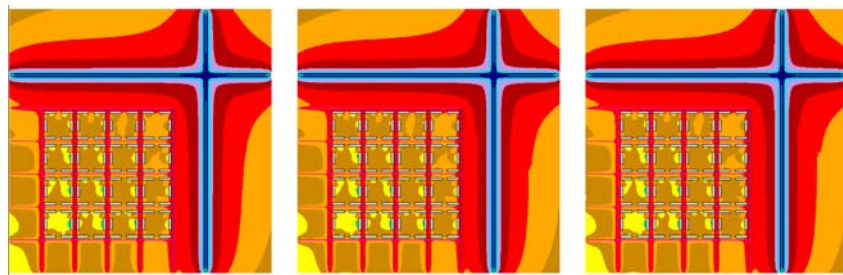


Fig. 10: Calculation of 40401 Receptor Levels (400 MHz PC), 52 road elements, 96 buildings

Max. Tolerance (dB)	0.0 (i.e. all sources)	1.00	2.00
Mean difference (dB)		-0.11 dB	-0.16 dB
Standard deviation (dB)		0.10 dB	0.15 dB
Calculation Time (s)	609	101	86

Studies in the early '90 have indicated that fetching radii for reflectors can be quite small. For a real-life example, a 500 x 200 m area (10 m grid width) has been calculated with differing fetching radii (Fig. 11). It indicates that including reflections 30 m from source or receiver produces sufficiently good results with optimal calculation time.



Fig 11. Influence of fetching radius for reflectors

<i>Fetching radius (m)</i>	<i>0</i>	<i>30</i>	<i>60</i>
<i>Mean deviation (dB)</i>		<i>1.7</i>	<i>1.9</i>
<i>Standard deviation (dB)</i>		<i>1.2</i>	<i>1.3</i>
<i>Calculation Time (s)</i>	<i>250</i>	<i>1149</i>	<i>2104</i>

COMPLEX GEOMETRY

Producing consistent and plausible results when analyzing detailed geometry, such as complex barrier constellations and cantilever roofs, can pose difficulties. The strategy used should deal with reflectors that are placed in behind other reflectors. Multiple reflections are treated by permuting the reflectors near source and receiver. Side diffraction needs to be applied for all concatenated barriers as well as for combinations of high and low barriers (Fig. 7). In a 3-D situation, it is misleading to distinguish between vertical and horizontal sound paths, so rather a worst-case combination of 3 paths with 120-degree offset of planes might be recognized (Fig. 8).

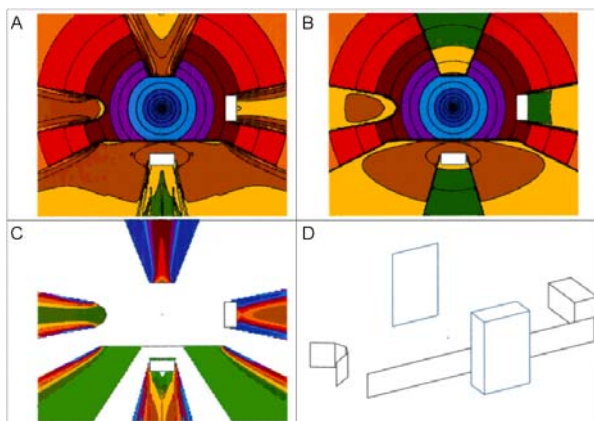


Fig 7. Correct handling of multiple reflections (A) for model (D) compared to a simplified calculation (B). Differences (C)

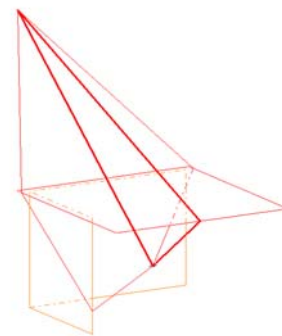


Fig 8. Determining vertical and horizontal sound paths using a worst-case combination of 3 paths with 120-degree offset of planes

CHECKING THE INFLUENCE OF ANY SIMPLIFICATION

Whenever simplification is done, the effect on result quality needs to be verified. The new draft German DIN 45687 [4] suggests the use of statistics to compare results from the simplified model with an accurate calculation for a sample number of receptor positions. Such a sample might be a separate grid or selected randomly from the original grid. Comparing the results will produce an average deviation and a mean square error.

When noise exposure of inhabitants is evaluated on the basis of a noise calculation in the same height as the grid calculation, façade levels may be interpolated from grid results provided at the grid resolution is less than 10 m and receptor points within buildings are specially treated by the software. When comparing the calculated and interpolated results for all façades of the Birmingham test case, the interpolated results showed an average deviation against the calculated façade levels of 0.34 dB(A).

Manipulating Grid Calculations

Some techniques can reduce the calculation effort. These should be documented and applied according to user-defined input parameters. The principal approaches can be:

- Two step calculation: Calculate a rough grid and interpolate linearly within the cell of the rough grid to produce a fine grid. Then, calculate the fine grid but only next to barriers and emitters and merge the two sets of grid results.
- Create a triangular net of relevant receptor points related to the positions of emitters and barriers. This will help the display large changes of noise levels due to e.g. barriers around their locations. For a fine graphic display of information within the triangles the vertex results may be interpolated. However, there is no indication about loss of accuracy as these results always look nice. In addition, any changes in geometry will change the receptor positions, thus making comparison difficult.
- Dynamically varying grid resolution dependant on the receptor's distance to the nearest barrier or source. Here, special caution needs to be taken for changes in the propagation condition of any sources at larger distances.

Calibration of Noise Maps with Measurements

Many lay people find noise maps that are based on complex data and intricate calculations difficult to understand and have difficulty evaluating the quality of the noise maps. Thus, validation that compares real and simulated noise levels is desirable. In much the same way as a sound level meter is calibrated during an assessment routine to reduce error, noise maps can also be calibrated [4]. Two approaches can be taken:

- Global correction of noise levels where the map can be adjusted “en-masse” to optimise the difference between calculated and measured values.
- Local correction of noise levels: By measuring close to sources under investigation, source levels can be estimated. A model describing the whole ambient condition is defined and sources with unknown emission are roughly estimated. An iterative technique finds emission values which best fit the measured data at the receptors while considering the other sources, reflections, diffraction, etc.

Experience shows acceptable results, and large deviations indicate the need to investigate this area and refine the model in more detail.

CONCLUSIONS

Making noise maps for large areas is a challenge for both users and calculation software. It is in the taxpayers’ interest to make realistic and accurate maps. Thus, the user must avoid oversimplifying the model. At the same time, the software must be able to cope with large models. Quality is obtained by making the process reproducible and traceable. It is therefore important that all steps within the process are clearly documented. The model should be built on available digital data. If simplification is needed it must be done in a reproducible, automated and documented manner. Specifically, geometrical handling and optimisation within the calculation core must be clearly documented. Simplification and optimisation must be validated with statistical analysis and measurements used to calibrate the model and ensure realistic maps.

REFERENCES

1. “Directive of the European Parliament and of the Council of 25 June 2002 (2002/49/EC) relating to the Assessment and Management of Environmental Noise”, European Commission, Official Journal (2002)
2. Various calculation algorithms
3. Manvell et al, “Geometric Post-Processing of GIS Data”, Proceedings of Internoise (2003)
4. DIN 45687 (Draft version) “Software-Erzeugnisse zur Berechnung der Geräuschemission im Freien - Qualitäts-anforderungen und Prüfbestimmungen”
5. Manvell et al, “Matching Noise Maps with Reality”, Proceedings of IOA Seminar “Noise Mapping – Which Way Now” (2002)
6. Stapelfeldt et al, “Quality assurance for the calculation of large noise maps”, Proceedings of Forum Acousticum (2002)