QUALITY ASSURANCE
FOR THE CALCULATION OF LARGE NOISE MAPS

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ABSTRACT

According to the EU Environmental Noise Directive [1], noise maps will be produced for all large agglomerations. The conclusions to be drawn from these maps require a fairly high standard of accuracy. However limited resources demand economic techniques to achieve this. Data import and post-processing as well as data and result management will influence these economics. Accuracy is influenced by the quality of model data, handling of reflections and simplification strategies to speed up the calculation. Based on noise maps, such as Birmingham and Bonn, the statistical influence of these effects on noise levels and population exposure will be addressed.

INTRODUCTION

According to the Environmental Noise Directive, noise maps will be produced for all large agglomerations. The size of the envisaged task demands an economic approach that takes accuracy into account.

Economics are influenced by:

- Data import and post processing
- Data and result management
- Simplification strategies to speed up calculation

Accuracy is influenced by:

- Quality of model data
- Quality of geometric analysis, i.e. propagation algorithms and their realisation in software tools
- Simplification strategies to speed up calculation

Noise mapping deals with large scale analysis, e.g. the whole of Nord-Rhein-Westfalen or Thüringen, to predefine relevant areas of analysis (Fig. 01) but at the same time detailed geometry analysis is important when evaluating barrier effects. So balancing the two aspects is a challenge to software and users.

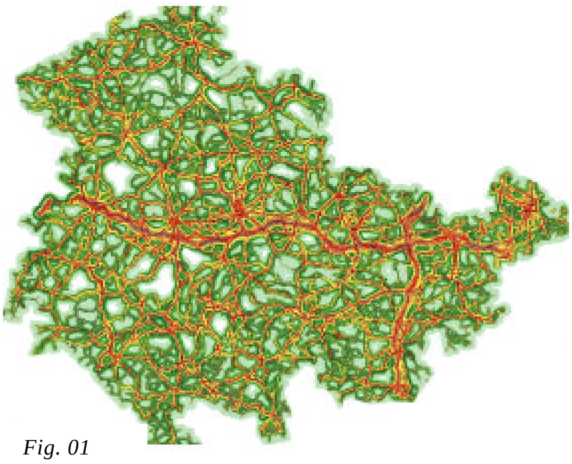


Fig. 01

Noise Map of Thüringen (18.000 km² , roads and terrain)

The conclusions to be drawn from noise maps might lead to significant investments and therefore a high standard of accuracy is mandatory.
Accurate models will not just be essential next to the emitters, as conclusions about silent areas and facades are of interest as well.
Simplifications, such as neglecting buildings off the main roads, will lead to an overestimation of noise impact and in consequence we might ask:
Why not assume free propagation, predict high noise levels and hope for attracting investments and subsidies?

Instead of this, we should have the taxpayers' interests in mind and improve confidence in the map and the authority by using realistic models and produce results, which correlate with reality.

CALCULATION STANDARDS AND THEIR IMPLEMENTATION

Accuracy depends on calculation methods [2], described in regulations, as well as input data. Each regulation seems to have individual pro and cons. Hopefully the "Harmonoise Project" [3] will avoid the worst cons. To give some examples:

- VDI 2720 : switch from double to single screen
- ISO 9613 : influence of low barrier ignores ground reflection
- CRTN : looks for reflectors with no respect to 3-d terrain
- RLS 90 : strange effect for traffic light influence
- 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

<u>Implementation by software developers and users</u>

Software developers have to interpret the vagaries of regulations and standards. Typically any complex geometry of an acoustic model has to be reduced to a simple geometrical situation described in the regulation. This leads to deviating results in different software packages.

Software developers have to offer a tool, which works on detailed as well as large models. So various switches are provided and the user needs documentation and training to make adequate use of them.

For the noise mapping task a desired accuracy needs to be defined and by applying statistical tools the user should prove that his settings for the calculation were adequate.

SETTING UP THE MODEL

In cases where there are no GIS data available it is tempting to use attenuation areas (e.g. instead of modelling individual buildings). However a "user based" decision on attenuation rates, perhaps based on "catalogue model situation" is a lengthy and ambiguous process and no range of accuracy can be defined for the results. So it is often more economical to invest in setting up a proper GIS system first.

Such GIS data is already widely available. However, its degree of detail 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, e.g.

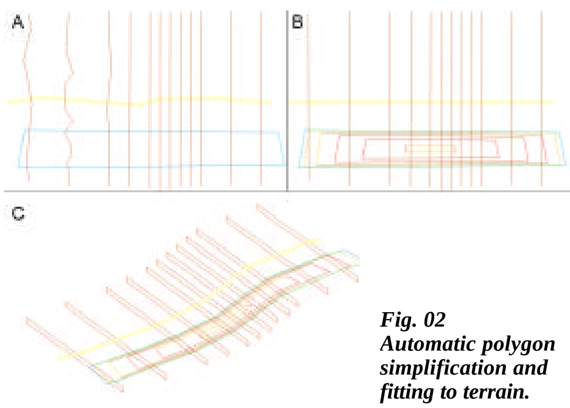


Fig. 02
Automatic polygon simplification and fitting to terrain.

- Simplify geometry of contours, buildings and emitters depending on task (Fig. 02)
- Generate attenuation area parameters from discrete buildings.

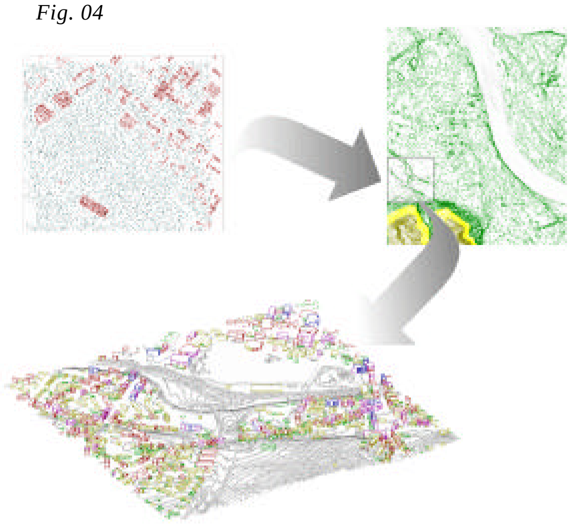
Economic generation of a model
A wide range of 2-D and 3-D GIS data formats are in use and specific converters are needed to import them into the acoustic model. As these data have not been set up for an acoustic simulation, post-processing is needed, such as:

- Check multiple geometry, e.g. due to part of a road polygon being digitised forward and backward
- 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 (Fig. 02)
- Concatenate singular vertexes to polygon objects to allow proper screening and noise exposure statistics (Fig. 03)
- Allocating attribute information by linking objects to database entities or supported by logical or geometric pre-selection

Fig. 03

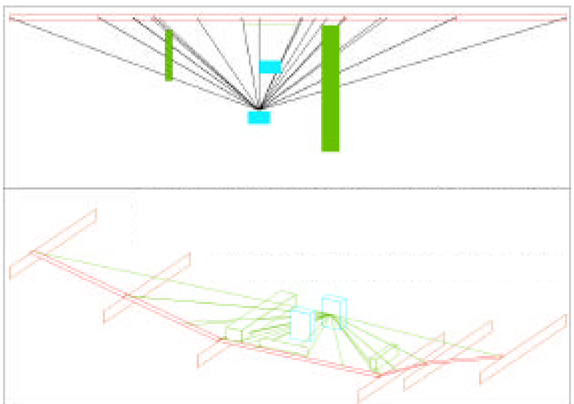
It has also proved helpful to add new attributes or define routines to organize post-processing in user-supplied DLLs without extra support by software developers.

Fig. 04



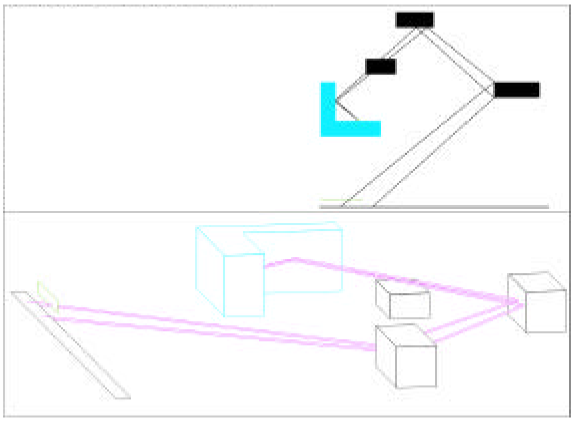
During recent years Laser Scan Data collected from aircraft have become available. This can be used to automatically generate a 3-d model though it cannot recognize whether an object is "non stationary".
Alternatively such data can be merged with existing 2-D GIS data to produce high quality 3-D terrain and building models. In a pilot project (City of Bonn) terrain accuracy was within 30 cm. (Fig. 04)

ACCURACY OF THE CALCULATION SOFTWARE
Point sources, which are most relevant in industrial calculation, are no problems for different techniques of geometrical analysis. However, for line sources, e.g. roads, various techniques are used to process the geometry. As the major source in noise maps, how these are handled have great impact on results. Methods include "fixed angle search", "fixed length segmentation" and "method of projection" (Fig. 05).



This latter method has the advantage of producing a steady change in results for any minor displacement of receptor position. Within any sub-segment it creates, the barrier influence also changes reasonably steadily so that assuming one representative position still leads to high accuracy results.

Fig. 05



When combining this method with a "virtual mirror source + barrier" logic for reflections, the stretch of road that actually contributes to the noise level at the receptor is automatically recognized. (Fig. 06)

This strategy will also avoid missing out reflectors that are placed in behind other reflectors. Multiple reflections are treated by permuting the reflectors in the neighbourhood of source and receiver.

Fig. 06

Side diffraction needs to be applied for concatenated barriers as well as for combinations of high and low barriers. (Fig. 07)

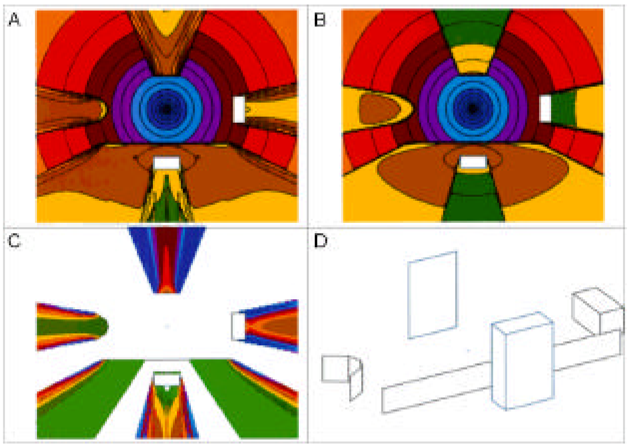


Fig. 07

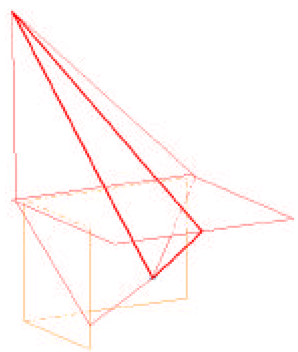


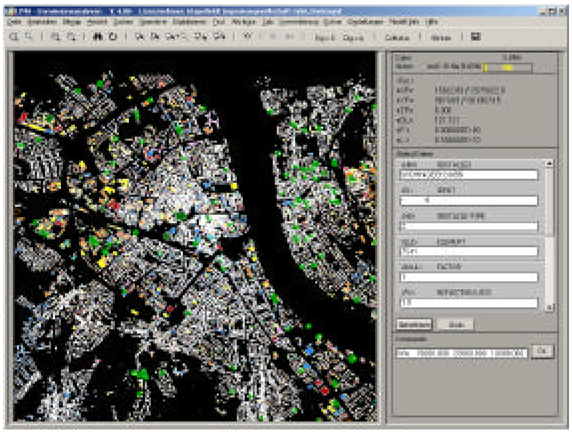
Fig. 08

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. 08)

<u>Simplifying the calculation procedure</u>

To guarantee reasonable calculation speed, all objects of the relevant model area need to be kept in memory. This is no more a hardware issue, but 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 m – 3000 m are chosen, but quality checks should be applied. To ensure steady results at the edge of any "calculation tile" the relevant model area should exceed the result area by the size of the fetching radius. For calculation areas as small as 1 km^2 and a radius of 2000 m, 25 km^2 of model area is required.



For the city of Bonn (Fig. 09) this means about 212.000 obstacles.

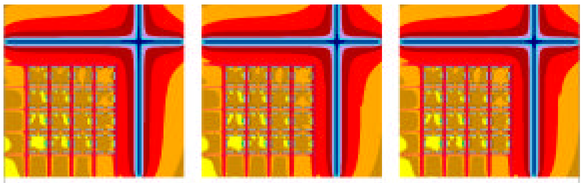
With a radius of 3.000 m and hilly terrain, such as in Hong Kong, one can expect of up to 1.000.000 objects that need to be handled within the calculation. This will require machines with 256 MB memory. Separate, much smaller fetching radii are used to select relevant reflectors

Fig. 09

To reduce the calculation load, irrelevant emitters may be neglected. One common way is to neglect "small" emitters. However, this strategy 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 then define an acceptable maximal total error margin. (Fig. 10)

All the calculation techniques described above have been implemented in the LIMA software for almost 10 years and applied with success on a large range of noise mapping projects.

Fig. 10:
Calculation of 40401 Receptor Point NoiseLevels on 400 MHz, 52 Road Elements and 96 Buildings (eq. 384 barriers)



Max. Tolerance :	*0.0 dB*	*1.00 dB*	*2.00 dB*
Mean difference:		*-0.11 dB*	*-0.16 dB*
Standard deviation:		*0.10 dB*	*0.15 dB*
Calculation Time:	*609 sec*	*101 sec*	*86 sec*

<u>Fetching radius for reflectors</u>

Studies in the early '90 already indicated that fetching radii for reflectors need not to be very large. Based on a example area taken from the "City of Bonn" model, 3 cases have been calculated for a 500 m x 200 m area in 10 m grid width to demonstrate the influence of the fetching radius. (Fig. 11)
The example indicates similar to previous analysis that reflection needs to be cared for and that a fetching radius of 30m produces sufficient results

Fig. 11
Influence of fetching radius for reflectors

Fetching radius	*0 m*	*30 m*	*60 m*
Mean deviation		*1.7 dB*	*1.9 dB*
Standard deviation		*1.2 dB*	*1.3 dB*
Calculation Time	*250 sec*	*1149 sec*	*2104 sec*

VALIDATION OF SIMPLIFICATIONS

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 for Quality Standard Management to compare results, which have been produced, based on simplifications against 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.

NOISE EXPOSURE ANALYSIS

When noise exposure of inhabitants is evaluated on the basis a noise calculation in the same height as the grid calculation, it has been proofed in the Birmingham project, that façade levels may be interpolated from grid results. The width of the grid should not be larger than 10 m and receptor points within builds should be 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 0.34dBA with a standard deviation of 0.78dBA.
However this method has limitations at the corners of buildings where only one of the façades is facing a significant noise source. Of the 2457 façade positions in the test case, only 19 (just over 0.7%) had an error of between 3 and 4 dB(A) and there were no errors above 4 dB(A).

CALIBRATION OF NOISE MAPS WITH MEASUREMENTS

Noise maps will be made by simulations based on complex data and intricate calculations. Many people, including politicians responsible for noise policy, find these difficult to understand and will have difficulty evaluating the quality of the resulting noise maps. A validatory method to compare real and simulated noise levels is thus highly 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 [5]. However, the number of results, the possible adjustments that can be made and their interactions are more varied and complex.

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 the sources under investigation, the source levels can be estimated. A calculation model that describes the whole ambient condition is defined. Sources with unknown emission are roughly estimated. The calculation software then uses an iterative technique to find emission values which best fit the measured data at the receptor positions while considering effects such as other sources, reflections and diffraction.

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

CONCLUSION

Making noise maps for large agglomerations 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 and automated manner. The software most not be a black box. 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.

One should keep in mind that noise mapping is not a one-off event but a continuous process of modelling, calculation, mapping and planning with a maximum cycle of 5 years. This will result in additional demands for a data management system to monitor the improvements in the environment over time.

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