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NOISE MAPPING AND GIS: OPTIMISING QUALITY, ACCURACY AND EFFICIENCY OF NOISE STUDIES

H. De Kluijver*, J. Stoter**

* AEA Technology Rail BV, Concordiastraat 67, 3503 RC, Utrecht, Netherlands

** Delft University of Technology, Section of GIS Technology, Department of Geodesy, Faculty of Civil Engineering and Geosciences, Thijseweg 11, 2600 GA, Delft, Netherlands

Tel.: +0031302354750 / Fax: +0031302359150 / Email: h.dekluijver@nl.aeat.com

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ABSTRACT
Noise caused by industry and infrastructure is a major source of dissatisfaction with the environment in residential areas. Policies on noise control have been developed in most European countries. Noise effect studies are carried out to support these policies. Since important decisions are based on the results of noise effect studies, it is not only important to quantify noise effects, but also to have information on the quality and the reliability of the results. However the need for this information is often discarded. The quality of the results of noise effect studies depends on the quality of the data and models used. The integration of Geographical Information Systems (GIS) and noise models makes it possible to increase the quality of noise effect studies by automating the modelling process, by dealing with uncertainties and by applying standardised methods to study and quantify noise effects.

1 - INTRODUCTION
Noise can be defined as a feeling of displeasure evoked by sound. Infrastructure is the most significant noise source in residential areas. Therefore it is important to monitor the effects of existing infrastructure and to study the possible effects on the environment when new infrastructure is planned. These effect studies support the decision-making process. Based on these studies, the design with the least environmental impact can be selected and measures can be devised by which further environmental impact is reduced. Since noise transmission and the effect of noise on the environment have many spatial components, the use of GIS provides the possibilities to optimise the quality of noise effect studies.

2 - NOISE POLLUTION AND GIS
In noise effect studies noise levels are predicted with specially developed noise computer models. The results of the computer models can serve as input data for a GIS. Combined with other geographical information, such as locations of houses and buildings and areas sensitive to noise, noise effects can be quantified and visualised using functions available in GIS.
Quantifying noise effects includes:

- computing the area, which is affected by the noise
- determining the number of citizens who are annoyed by noise
- determining the number of noise sensitive buildings exceeding a desired noise level
- determining the areas within nature parks where a desired noise level is exceeded

Noise levels are calculated with special noise prediction computer models. Till now there is no widely used far-reaching integration of GIS and noise prediction models. GIS is only used as a pre- and post-processor in the study of noise pollution (for example to gather and store data and to calculate the impact of noise on the environment). As a consequence GIS and the available digital data are not optimally used. A preliminary study on the possibilities and advantages of an integrated system of GIS and noise prediction models shows the following benefits of an integrated system:

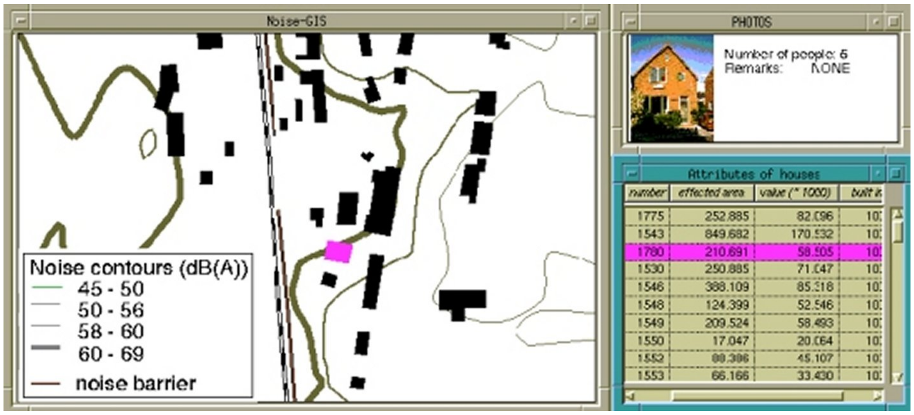

Figure 1: An example of combining data derived from different sources in a GIS.

- With a central spatial database unnecessary data conversion between both systems is prevented. This ensures the use of the same data.
- Input data for noise prediction models can automatically be generated, using available digital topographical and 3D information.
- With advanced interpolation techniques in GIS it is possible to obtain an accurate picture of the acoustic situation based on a limited number of sample points (calculated in a noise model).
- The accuracy and quality of the results depend on the scale and detail of the input data. The information density should be high enough but redundant information delays the computation of noise levels and effects considerably and should be avoided. A GIS-module can deal with this problem.

The points mentioned above improve the quality and efficiency of noise effect studies while reducing the data quantity, modelling effort and computation time.

3 - INCREASING THE QUALITY AND EFFICIENCY OF NOISE EFFECT STUDIES

3.1 - Integration of GIS and noise models

To support noise effect studies a central spatial database with the relevant geographical information is required. This database can be constructed and maintained with GIS technology. A tool is needed with which everybody who is involved in the study can access the data. With one central spatial database, the best use of the data contained within the database is guaranteed without the need to copy or convert it, which may endanger the quality and reliability of the data.

Often a substantial part of a noise effect study is the gathering of the relevant information in "the field" like the height of the surroundings (needed in the noise computer models) and the functions of buildings in respect to their sensitivity to noise. Much of this information is already digital available with designers and architects or with external commercial data suppliers.

The level of detail of existing digital topographical and height information is generally too high to use directly in noise computer models. For this reason it is necessary to generalise the available digital data before it can be used as input data for noise models. Nowadays the generalisation is done by an acoustic expert who (re)digitises the available (digital) information manually.

An integration of GIS and noise models will make it possible to generate noise data-models (input for noise computer models) automatically from existing digital geographical information. The mentioned fieldwork and digitalisation will hereby not be necessary any more. A conversion program is required by which the level of detail is reduced in a way which is dictated by the acoustics of the surroundings. This will promote the standardisation and efficiency of noise data-models, since noise data-models are no longer the product of subjective choices and the manual digitising of an acoustic expert. With this it is possible to generate large accurate data-models, which enables monitoring the noise situation, for example, of an airport, a city or an entire country. The use of 3 dimensional data-models in GIS would support the process of automatically generating data-models (see figure 2).

Implementing the noise calculation method in GIS would make conversion and exporting data to existing noise computer models unnecessary. However the complex noise computer models have a status of

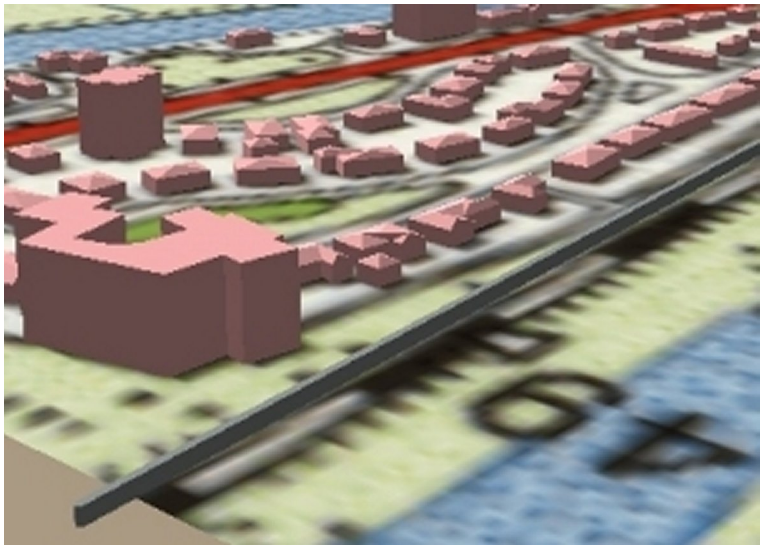

Figure 2: An example of using a 3D data-model of buildings in generating noise data-models.

confidence and it will be hard to replace them. Still with parts of the noise calculation method in GIS we can estimate noise levels and noise effects and indicate possible solutions to noise problems without the need to use complex computer models. Further research is needed on whether GIS techniques and functions to process spatial data could optimise the calculation process.

3.2 - Noise effects indisputably quantified

Noise levels are computed precisely by imposed methods in noise computer models, while on the other hand an indisputable instrument to quantify noise effects is lacking. This can lead to different decisions with different noise effect studies. The standardisation of noise effect studies will be enhanced when the methodology and the level of detail to quantify noise effects will be laid down in directives. These procedures can be implemented in a GIS-application. The aim is to obtain an unambiguous device to uniquely quantify noise levels. Results will no longer vary with the used methods. Since noise policies rely on the results of noise studies, this standardisation will support a consistent and indisputable noise policy.

3.3 - Level of detail of input data

Noise effect studies are sensitive to the level of detail of the following input data:

- observation points on which noise levels are computed
- locations, areas and objects sensitive to noise

A reliable result can only be obtained if the information density is sufficiently high. However, redundant information should be avoided since time to prepare data and computation time increases with information density. In noise effect studies compromises often have to be made between processing time and information density. A better option would be to adjust information density to fluctuations in noise levels. A high density of information is only required on areas with high variation in noise levels. As we move away from a noise source, the noise levels reduce 'quickly' close to the source, behind objects, such as noise barriers or buildings, and near changes in ground-reflection or absorption, such as water surfaces. Noise levels reduce 'slowly' or not at all at a great distance from the source (in the absence of obstructing objects) and parallel to the source (road or railway).
With these assumptions in mind suitable locations of observation points can be chosen using spatial functions in GIS (see figure 3). A similar approach can be used for areas and objects that are sensitive to noise. For example, the accuracy to which the location of houses and other noise sensitive buildings is known must be very high near the noise source. Less accuracy is required further away. Exact locations of houses are needed close to the source while residential areas or districts will suffice further away.

3.4 - Dealing with uncertainties and inaccuracies

Since important decisions are made based on the results of noise effect studies, it is not only necessary to have the results themselves, but also to have information about the quality and the reliability of these

Figure 3: Density of observation points is dependent upon the variation in noise levels.

results. The reliability of the results depends upon the accuracy and quality of the source data and the validity of the noise models used. Techniques for dealing with data inadequacies and for disclosing the quality of the results should be applied in noise effects studies. These techniques include:

- taking the errors in the data and the models into account by methods of error propagation
- exposing the quality of the results by estimating and quantifying potential errors
- replacing visualisation of exact noise contours by contours with uncertainty bandwidths
- replacing exact figures by gradual judgements

4 - CONCLUSIONS

Figures and visualisations in noise effect studies are produced by "black boxes" that give the decision-maker no insight into the methods used to quantify noise effects or their related errors. On the other hand the results are often accepted as being exact and true despite their lack of insight. However, with the methods proposed in this article it is possible to give a more valuable meaning to the results of noise effect studies. From the previous the conclusion can be drawn that the integration of GIS and noise models provides the possibility to increase the quality of noise effect studies.