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NOISE MAPPING AND GIS; OPTIMISING QUALITY AND EFFICIENCY OF NOISE EFFECT STUDIES

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Abstract

Noise caused by industry and infrastructure is a major source of dissatisfaction with the environment in residential areas. In order to assess and monitor the influence of noise, policies on noise control have been developed in most European countries. Noise effect studies are carried out to support these policies. Since significant decisions are based on the results of noise effect studies it is important to develop standardised methods for the noise mapping process. Moreover, it is not only important to obtain results, but also to have information on the quality and the reliability of the results. And yet, the need for this information is often discarded. The quality and reliability depend on the quality of the data and models used.

An appropriate use of Geographical Information Systems (GIS) in mapping noise effects makes it possible to optimise quality and efficiency of noise effect studies by automating the modelling process, by estimating and exposing uncertainties and by developing and applying standardised methods to study and quantify noise effects.

Résumé

Le bruit causé par l'industrie et par les infrastructures est une source majeure de mécontentement dans les zones résidentielles. Afin d'évaluer et de surveiller l'influence du bruit, des politiques de gestion du bruit ont été développées dans la plupart des pays européens. Des études sur les effets du bruit sont menées pour contribuer à ces politiques. Comme des décisions importantes reposent sur ces études sur les effets du bruit il est important de développer des méthodes standardisées pour le processus de cartographie du bruit. Qui plus est, il ne s'agit pas uniquement d'obtenir des résultats, mais il importe également d'obtenir une information sur la qualité et la fiabilité de ces résultats. Néanmoins ce besoin n'est pas souvent pris en compte. La qualité et la fiabilité dépendent de la qualité des données et des modèles utilisés.

Une utilisation appropriée des Systèmes d'Information Géographique (SIG) pour la cartographie des effets du bruit permet d'optimiser la qualité et la fiabilité des études, en automatisant le processus de modélisation, en estimant et en représentant les incertitudes, en développant et en appliquant des méthodes standardisées pour l'étude et la quantification des effets du bruit.

Keywords: decision support, environmental modelling, error-sensitive GIS, uncertainty analysis

1. Introduction

Infrastructure is the most significant noise source in residential areas. Therefore it is important to monitor the noise effects of existing infrastructure and to study the possible noise 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.
To quantify and visualise noise effects an extended spatial database, spatial tools and computation force are needed. For that reason GIS is used in studies on the environmental impact of noise. The noise levels are computed in special developed simulation computer models and GIS is used to quantify and visualise noise effects based on these noise levels.

At this moment a universal method to obtain noise effects with GIS tools is lacking. This leads to differences in the quality and accuracy of different noise studies. Consequently, controversial conclusions may be drawn in these studies. Therefore, standardisation of the noise mapping process is required.
Since important decisions are made based on the results of noise effect studies, an important issue is: "What is the meaning of these results?". 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 the mentioned lack of insight.
A considered use of GIS in noise effect studies can improve efficiency, data management, quality, (insight in) accuracy and presentation. This will support the standardisation and reliability of noise effect studies as will be shown in this paper.

2. The need for standardisation

Since noise policies rely on the results of noise studies, standardisation will support a consistent and indisputable noise policy. This is also recognised by the European Commission (see text border).

> The DG Environment of the European Commission is preparing a proposal for a Directive on Environmental Noise. An important part of this directive is noise mapping. The goal of this directive is that cities with more than 100,000 inhabitants produce noise maps and action plans and repeat this every five years. The outcomes will be collected by the European Commission, who will publish the results. It is the intention of the European Commission to use the collected data for setting environmental targets and for developing strategies to achieve those targets (European Commission, 1996).
> The results originating from different member states can only be combined if all members use the same indicators for noise exposure and the same methods to calculate these noise exposure levels. Nowadays this is not the case. Comparative studies have shown dramatic differences between the outcome of these methods (Ten Wolde, 1999). Therefor the mentioned directive will include a proposal for standardising indicators for noise exposure, assessment methods *and* noise mapping.

In search for possible standardisation the authors of this paper tried to answer the questions "How can noise effect studies be more accurate, meaningful, reliable, unambiguous and how can noise effects be examined more efficient?". To give an answer to these questions they studied the whole process of noise mapping. Noise mapping is the total of the following processes:
- collecting raw data

- computing noise levels in computer models
- storage and querying of these data
- determining noise effects in GIS by combining noise levels with the locations of people, animals and/or their activities (in areas, houses and other buildings) in regard to their sensitivity to noise
- presentation of the impact of noise on the surroundings by means of visualisation tools in GIS

Noise computer models and GIS are often used as two independent separated systems. Hence, data exchange and conversion between those systems is often needed. This is a potential source of errors since it causes confusion about the actuality and validity of the data and it may introduce conversion errors.

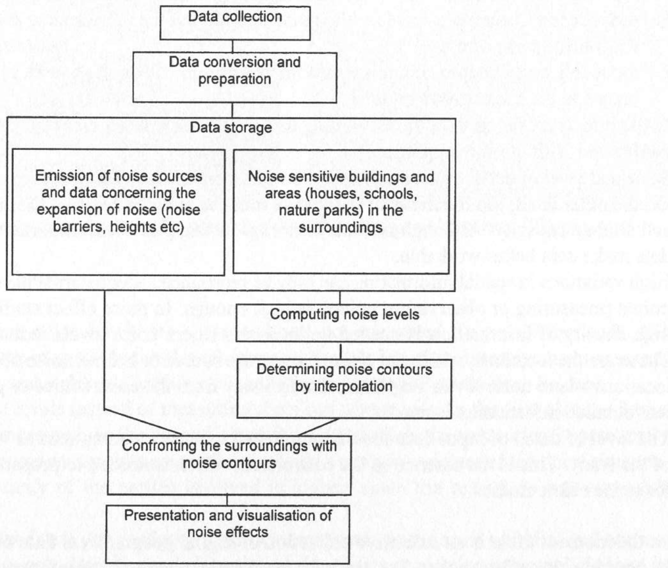

Fig. 1: schematisation of the noise mapping process

It is evident that the quality of the final results depend on the quality of the data and the methods used in every step of the noise mapping process. In order to improve the efficiency the level of detail of the complete noise mapping process should be adapted to the purpose and desired level of detail of the entire noise effect study. This also means, finding a balance in the level of detail and the exactness between the different steps in the noise mapping process. It makes no sense to put a lot of effort in the accuracy of one step while another step in the process is done with less detail, loosing the earlier obtained details. In conclusion, the accuracy of the methods and input data used should be in balance and adapted to the desired level of detail of the final results.
To give a more valuable meaning to the results, insight in the quality of the results is needed. For example: the calculated number of annoyed people should be presented together with the variation

the existing (complex) noise computer models have a status of confidence. Therefore it will be hard to replace them.

5. Determining noise contours

Noise contours are computed in GIS by interpolating noise levels computed on a raster of points. Figure 3 shows part of a noise model with the calculation points used to calculate noise levels caused by a railway. The way this interpolation is done is not standardised, neither is the density of the raster of calculation points. Therefor the location of noise contours depends on subjective factors. This is not desirable since important decisions are based on these contours, while these decisions should be unbiased. The development of directives for the density of the used raster and for the interpolation method would increase the standardisation of noise effect studies.

An accurate and complete picture of the noise situation in the surroundings of a noise source can only be obtained if the density of points is sufficiently high. Like mentioned before the density should be high close to the noise source and near noise obstructing objects, while parallel to the source and further away from the source less calculation points are needed and desired. This results in a decreased computation time. Obviously, the needed density of calculation points also depends on the desired level of detail of the study, which is dictated by the purpose of the study.

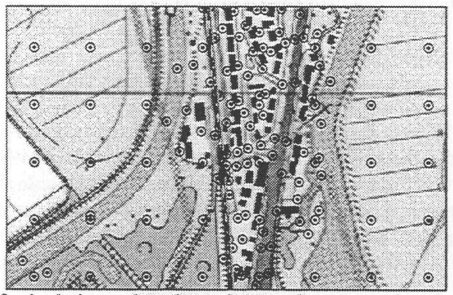

Fig. 3: density of calculation points dependent on the expected variation in noise levels

The Dutch acoustic software is capable of determining noise contours by integration. However, this software needs a regular raster of calculation points. The used density is often based on a compromise between accuracy and computation time. A better option would be to adjust information density to fluctuations in noise levels, like argued before. Computation time is reduced while a higher level of accuracy is achieved.

Interpolation in GIS does not require a regular raster of calculation points. From a pilot study, in which noise contours were calculated in GIS, it can be concluded that 90% of calculation points and accompanying computation time could easily be saved (see figure 3). The continuous picture of figure 4 is based on the noise model partly shown in figure 3. About 1,000 calculation points were used in total for an area of 3 by 2 kilometre (600 calculation points in a regular raster of 100 by 100 meter, with 400 extra points to increase the density near the source and near noise obstructing objects). GIS-functionalities can automatically determine appropriate locations for calculation points. In acoustic software, the same result can be obtained with a raster of 25 by 25 meter with 9,600 calculation points in total. This would lead to a ten times higher computation time.

Another optimisation is to increase the quality of noise contours. Further going optimisation is possible with advanced interpolation methods available in GIS which take the properties of spatial spreading of noise into account.

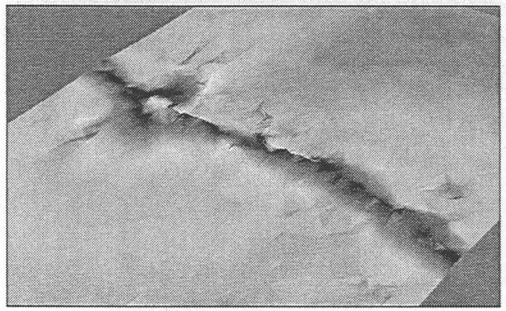

Fig. 4: continuous picture of noise levels after interpolation of calculation points

6. Quantifying and visualising noise effects

Noise effects are quantified and visualised by confronting the obtained noise contours with information on the surroundings, such as locations of houses and other buildings and/or areas with activities sensitive to noise (see figure 5). Functions available in GIS (see figure 5) are used in this process.

Quantifying noise effects includes:

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

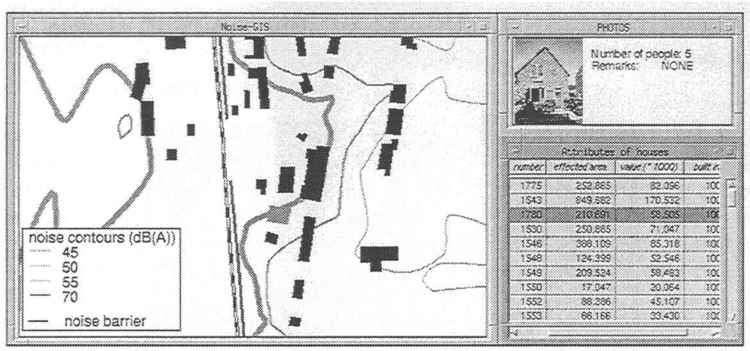

Fig. 5: determining the number of houses where the dictated noise level is exceeded by combining noise contours with the locations of houses

The presentation of the results is not complete without a presentation of the quality of the results. As mentioned before, the reliability of the results depends upon the accuracy and quality of the input data and the validity and accuracy of the computation methods 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

7. Cumulating noise

Cumulating noise levels originating from different sources is a very important factor in the study on noise effects. Usually the overall annoyance to noise is determined by more than one noise source and therefore the influence of new infrastructure depends on the existing noise level as well. Cumulating noise sources is also an important issue in regard to "bundling noise sources". Bundling noise sources will result in less noise pollution than spreading sources over a wide area. For example: a new highway next to an existing railway is, from an acoustic point of view, better than designing these noise sources parallel but wide apart. In conclusion, cumulating noise should be considered in noise studies. The analysing possibility in GIS to cumulate noise levels originating from different noise sources is therefore an improvement in noise effect studies.

The annoyance to noise depends upon many variables, like sound intensity, frequency and variation in time. Several studies on noise show a correlation between the time averaged noise level and annoyance. Annoyance is also related to many non-acoustic factors of a social, psychological or economic nature (PBNA, 1995). It is found that the average annoyance (averaged individual reactions) is related to the type of noise source. For example, aeroplanes tend to be more annoying than trains even if the noise levels are the same. Dutch studies on the response of people to different kinds of sources have resulted in response functions (Miedema, 1992, see figure 6).

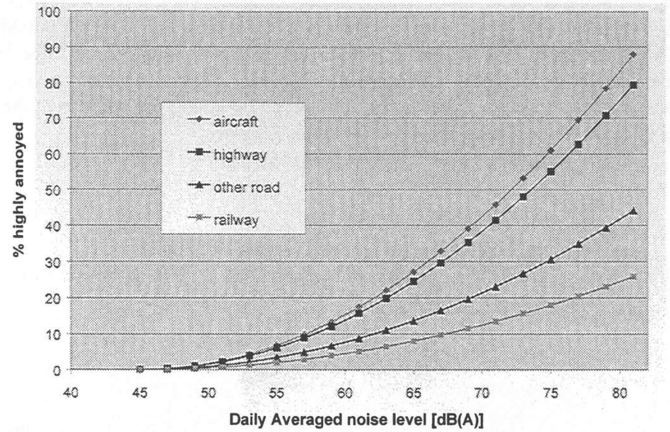

Fig. 6: the percentage of interviewed people who were seriously annoyed depends on the noise level and the kind of noise source

By taking all the noise sources and their respective annoyance factors into account and implementing these response functions in GIS the total "cumulated" acoustic situation and related annoyance in the area can be calculated (see figure 7).

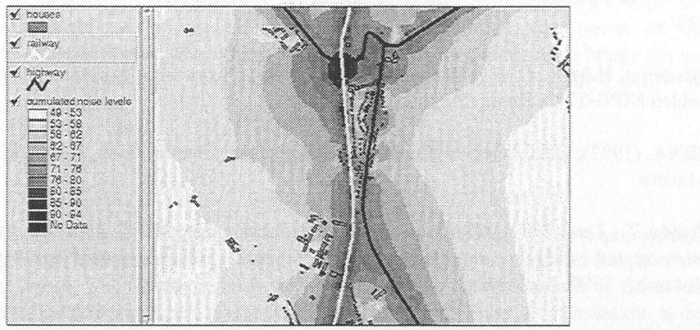

Fig. 7: result of cumulating noise levels originating from highway and railway

8. Conclusion

An appropriate use of GIS in mapping noise effects makes it possible to optimise quality and efficiency of noise effect studies.

A universal method to map noise effects is lacking. 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, so results will no longer vary with the used methods.

Since significant decisions are 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 results. A proper use of GIS in noise effect studies, enables estimating and exposing the uncertainties of the results based on the data and methods used. An important issue in this, is that the efficiency and meaning of noise effect studies are served by letting the purpose of the study dictate the level of detail of the results and the allowed uncertainties.

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