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NOISE MAPPING - A POWERFUL TECHNIQUE FOR PREDICTION, EVALUATION AND ASSESSMENT OF NOISE IN CITIES

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SUMMARY

It is important to evaluate the differences in noise impact thoroughly when decisions between possible alternatives in projects that deal with city planning are dicussed. An important step in this evaluation process is the calculation of noise maps for the regarded urban areas. The procedure is demonstrated without algorithms and formulas, because these depend on the national standards and other regulations. The calculation may take into account screening and reflection by objects like buildings and screens and other topographic properties. With the noise maps or respectively the corresponding data files the possible alternatives can easily be ranked with respect to the lowest noise impact for all given alternatives. If such a data file of a city or a part of it exists, this can be used in all decisions that may influence the noise situation.

INTRODUCTION

A noise map is the basic tool to minimize the noise impact on population when planning alternatives are regarded. The expression „noise map“ is used in this context for all the project data files of a city or a part of it and all the possible outputs of a prediction calculation. The well known coloured pictures are only one possible method of presentation.

The data acquisition and the depth of description of the real world by geometric and acoustic data determine the „worth“ of the resulting project file. If it shall be used for the detailed analysis of noise levels in a reflection determined backyard, the input data must be more accurate and more detailed, as if the coloured picture of the noise distribution in large areas is the only wished result of the prediction calculation.

If a noise map shall represent the real noise distribution for a given situation, screening , absorption and reflection have to be taken into account. For ranking of planning alternatives it is often sufficient to calculate only first order reflections. In screened areas surrounded by buildings it may be necessary to sum up all reflections till the 10th order.

The calculation of mean sound pressure levels on a grid and appropriate interpolation techniques lead to a noise map presentation. If such a noise map exists for all regarded alternatives, these can easily be ranked with respect to noise levels and number of persons that are annoyed.

CALCULATION OF NOISE LEVELS FROM EMISSION DATA

The calculation algorithms are described in national and international standards and shall not be discussed here. The basic calculation element determines the sound pressure level at a given point from the noise emission of a point source at another given point. It is therefore necessary as a first step of such a calculation to subdivide extended sources like roads into so small elements, that these can be simulated by point sources without lack of accuracy.

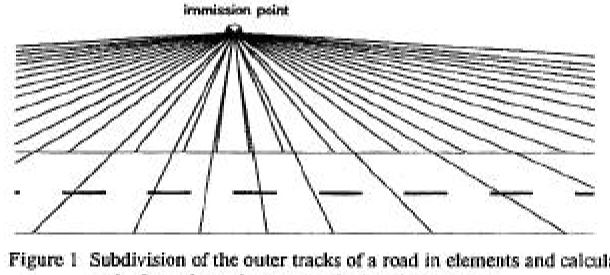

Figure 1 Subdivision of the outer tracks of a road in elements and calculated paths from these elements to the immission point

For the calculation of noise immission from a road it is sufficient to regard the two outer tracks and to replace the existing traffic flow by these two sources with half of the traffic on each.
Figure 1 shows the subdivision and all the paths from the element midpoints to the immission point, for that the sound contribution is calculated in the given situation. The elements are smaller near the immission point and larger at greater distances.
Similar procedures are used when calculating the noise impact from extended area-sources.

Theoretically the intersection of each path with each object has to be calculated when **screening** and reflections have to be taken into account. In practice it is necessary to make some approximations, because otherwise the exploding number of calculations would reduce the chance for an acceptable calculation time to zero. The problem in screening calculation is not the usually discussed screening algorithm for one or more screens with different heights, but the proper approximation for the shortest path through a 3-dimensional arrangement of objects like a city with thousands of complex shaped buildings.

Objects like buildings or walls can raise noise levels by **reflections**. This has to be taken into account, if no direct (unscreened) path exists from the source to the region of interest.
The calculation of reflections can be carried out by using the mirror image method. Figure 2 shows the principle of this method with three walls W_1, W_2 and W_3 and a third order reflection between source and receiver. If the original source is mirrored at wall W_1, this mirror image Q_1 at wall W_2 and the new mirror image Q_2 at wall W_3, we get the position of image Q_3. The distance between Q_3 and receiver IP is equal to the length of the real path Q_0 - P_1 - P_2 - P_3 - IP. With the absorption coefficient α of the walls, the sound intensity is weakened by a factor $(1-\alpha)$ at each reflection point. If one or more objects M are crossed by the reflected ray, screening has to be taken into account additionally by one of the described methods.

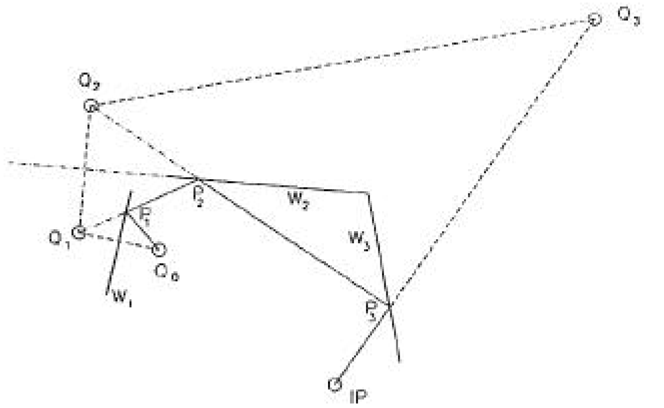

Figure 2 Calculation of a reflection of third order from source Q_0 at the receiver IP with the image source method

Figure 2 explains the principle of the calculation with a point source. When the source is extended like a road (line source) or a parking area (area source) this extended source must be subdivided into sufficient small elements and these are replaced by point sources for the calculation. Two steps are necessary to make no fault in this subdivision.
In a first step the extended source is subdivided by lines projecting all objects to it. Then in a second step each resulting element is subdivided further, if it's distance to the receiver point is smaller than twice the largest dimension of the element.
This subdivision is another one for each receiver point, because otherwise the smallest necessary extension defines the general extension of all elements. The dynamic subdivision is necessary to keep calculation times for extended sources like roads acceptable.
Fig. 3 shows all the rays that have been calculated to get the sound pressure level at an immission point in a backyard with Buildings of 25 m height at every side, where the rays can only penetrate this region by two openings at the front and the right side. The possible sound rays from the road in front have been calculated with reflections from 1st to 20th order (for reasons of visibility only rays till 8th order are shown in figure 3).

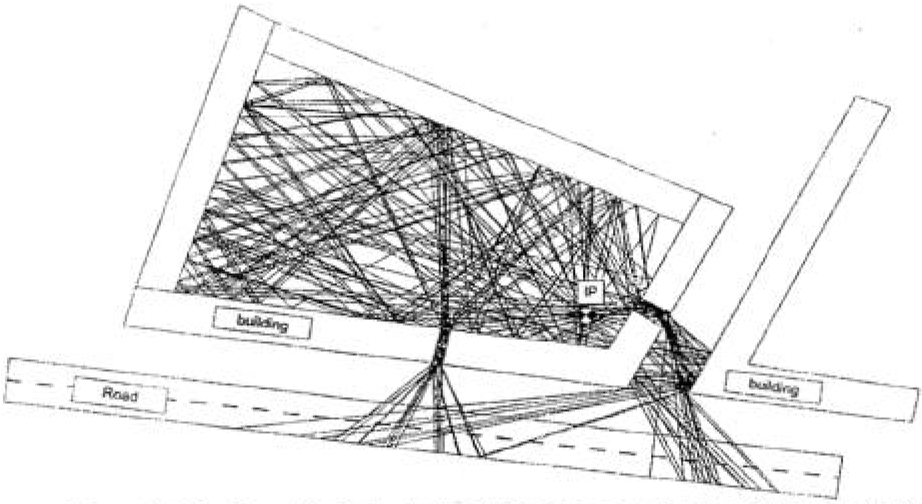

Figure 3 Calculation of noise level at point IP in the backyard with reflections to the 8th order

EVALUATION OF A NOISE SITUATION USING A NOISE MAP

Such detailed analysis as shown in figure 3 can be „extracted" from the noise map data file for a limited region only, because otherwise the calculation times would raise dramatically. For usual noise maps it is sufficient to take first order reflections into account.

When a noise map shall be produced, the calculation is reapeated for an automatically generated grid of immission points. The time needed for the calculation of noise levels at each of this points depends on many conditions like the concept used for the subdivision of extended sources, order of reflections, the hardware used and not at least the cleverness of the programmer who had developped the software.

Figure 4 shows a calculated noise map for a little town, where the inhabitants suffer under the noise load from about 16000 cars/24h, that drive through the northern part of the village.

Such a noise map is a very easy to use information system for consultants, planners and authorities. The existing situation can thoroughly be investigated and possible alternatives and improvements can be assessed.

The complete region is subdivided in different areas and for each of these areas the number of persons living there is defined. This distribution of inhabitants can also be estimated from the noise map file by scanning over the chart and summing up the people in all houses by using the dimensions and the height of each house.

In the example figure 4 such a calculation leads to 925 houses and about 13000 inhabitants.

There are some key numbers for the evaluation of such a situation. One of them is the number of people living in an area with equivalent noise levels more than 65 dB(A), because this has prooved to influence well-being and health. By scanning over the map we learn that 1072 persons suffer under such a noise load by day and even 273 persons by night.

It shall now be evaluated, what an improvement could be achieved, if a planned perimeter road would be built. For this situation a further noise map is calculated. Figure 17 shows this situation with the main traffic on the new northern ring road.

If different situations shall be compared in regard to the noise load of the inhabitants, two area-specific variables should be encluded in such a consideration. This two variables are the number of inhabitants P_i and the noise level L_i for each area element i. An important parameter value is the limiting value L_{lim} for the maximum equivalent sound pressure level.

An adequate evaluation formula for the total noise load of a region is

$$NL = \sum P_i \times 10^{k \cdot (L_i - L_{lim})}$$

where the summation is carried out for all area elements of the region. The constant k defines the steepness of the function and should be derived from the increase of annoyance with increasing noise level.

With

$$k = \log(2) \approx 0.03$$

an increase of 10 dB doubles the value of NL. Although this approach seems to underestimate the increase of annoyance with increasing noise level, it is often used and shall therefore be applied for the noise map of figure 4. (It is not possible to discuss the fundamentals of noise evaluation further in this paper).

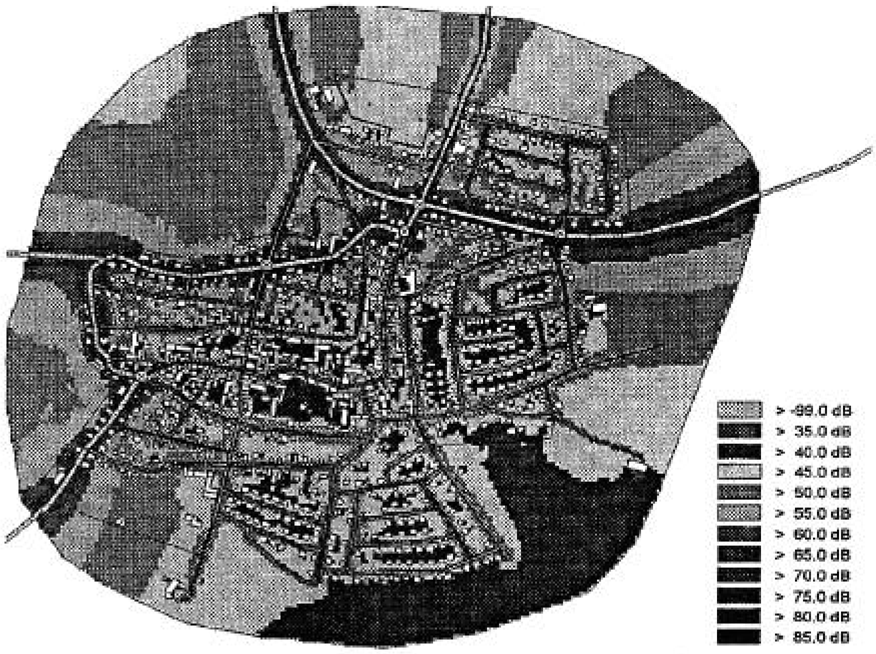

Figure 4 Noise map of a little town of 13000 inhabitants - calculated with a grid of 10 m and with 23000 points

The noise map of figure 4 has been calculated with a 10 m grid. When the stated formula is evaluated, the given expression is calculated for each 10 m x 10 m element and summed up. The result is

$$NL_{day} = 9485$$

and

$$NL_{night} = 10987$$

The situation at nighttime is therefore more severe than at day.

The evaluation scan over the map with a planned alternative with a new perimeter road (not shown here) gives the following results:

11 persons live with a noise level over 65 dB(A) at day and 2 persons at night.

The noise load is now

$$NL_{day} = 572$$

$$NL_{night} = 658$$

The situation will dramatically be improved with this planned traffic concept. This conclusion might seem to be trivial in this case, but the demonstrated technique of evaluation with a one number rating works also in much more complicated alternatives.

CONCLUSIONS

Traffic is the main reason for noise load in residential areas. With modern software tools it is possible to calculate the noise levels by taking into account the parameters of the traffic flow, the topographie of the environment and screening and reflections caused by buildings and other objects. Such a noise chart gives a quick overview to the complete noise situation of a city and allows to go into a very detailed analysis where this is necessary. When different planning alternatives shall be evaluated, this can easily be done by calculating and summing up the noise load for defined regions. Noise maps are a highly efficient information system for city planners and all those, who have to deal with noise abatement in residential areas.

REFERENCES

Calculations and figures of this paper have been made with the program Cadna/A of DataKustik GmbH