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CALCULATION MODELS FOR NOISE PROPAGATION OUTDOORS

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INTRODUCTION

In environmental acoustics we are interested in noise impact studies. The knowledge of the noise immission conditions can help to either reduce the noise of the sources, or to define protective measures within the propagation path, or at the location of the receiver. In order to know the noise immission conditions, it seems natural to simply take measurements. But this turns out to be quite a difficult task. Many noise sources, such as road traffic, are irregular in their behaviour. The influence of weather conditions can change the noise at the source and in propagation. Many parameters affect noise propagation over larger distances, and some of these are not very well known, and not easy to measure. Unfortunately all these parameters are not constant. This means that a real measurement usually does not solve our problems. It can never be more than a sample taken from a multitude of conditions, and we must try to establish what can be done with it. This task requires experience over many different measurement and propagation conditions. Experience can only be useful, if it is related to physical and practical parameters for each case encountered. Such an arrangement of past experience is what I would like to call an acoustic model.

PURPOSES OF A MODEL

There are two main purposes for using an acoustic model for noise propagation outdoors. The first one is to provide a basis for evaluating any measurement made in a practical situation. The evaluation is usually useful, if we can compare the results to levels that were established as legal limits in some law or regulation. This means adapting the measured levels to average conditions of whole days or nights, and perhaps also to average conditions for these periods over a whole year. By knowing the conditions at the time of measurement, the conditions defined or implied in the limit rules, and the relations of a suitable model we can achieve our goal of adapting measurement levels. No measurement is complete, unless this adaption is either done, or unless all elements that could be needed for the adaption are stated as carefully as possible.

The second purpose goes beyond the use of measured levels. If we trust the experience collected and evaluated in the process of developing a model, we can use it to extrapolate in time, and calculate the noise immission levels to be expected in the future. This can mean some other configuration of the sources, such as increased or modified traffic, or the simulation of new sources, or the evaluation of measures of protection that we hope to realize. It is absolutely necessary to apply all available knowledge in order to find the optimum configuration of each protective measure. The second purpose of acoustic models is therefore to replace acoustic measurements by properly applied previous experiece. Of course this application will include theoretically established principles in addition to empirical data and rules.

NOISE SOURCES

The impact of noise immissions can be due to a variety of acoustical sources. The most important ones are road traffic, railway traffic, airborne traffic and industrial noise sources. For road traffic the source description must include the difference between passenger cars and lorries, as well as their respective driving conditions at the locations of interest. It is usually not possible to consider the engine parameters and gear positions in detail. Average empirical relationships as a function of the mean driving speed are used instead. The location of a virtual sound source at a specified height above the ground, which is used to represent a vehicle, is an important parameter. Here the development of lorries with exhaust pipes above the vehicle are a definite problem, both for modelling traffic and for environmental protection as a whole, because many barriers already in use today are too low for this source location. So far, the directivity pattern of road vehicles has usually not been taken into account, but there is evidence that it may help to improve the models in some cases. In all cases where the results of noise immission calculations can be expressed as a mean energy level Leq, it is only the type and number of vehicles that need to be considered. Then many sophisticated and sometimes complicated theories concerning the variability of traffic flow and unequal spaces between vehicles do not need to be included. This is even a very valid reason for preferring Leq as immission descriptor.

Railway noise only exists at the time of a train passage. Then the very directive radiation of each wheel, and often additional contributions from the railway engine must be taken into account. The rolling noise of the wheels depends on the condition of the rails, and on the type of brake system used on the railway carriages. Modern intercity and high-speed trains use disc brakes, and operate at noise levels about 10 dB(A) lower than other railway carriages. Unfortunately this improvement is not yet in view for freight trains. Acoustic models of trains tend to become somewhat more complicated, if typical trains include both noisy and quiet vehicles. This is partly because there is an interest in knowing not only the overall energy mean level Leq, or the event-based exposure level SEL, but also the maximum sound level Lmax during the passage of a railway train.

Air traffic models include the pronounced directivity pattern of aircraft noise radiation. They must also allow for a considerable spread in flight paths and engine power settings, and thus include some parameters not needed for traffic on the ground. On the other hand, the influence of ground conditions on sound propagation is not relevant.

A particular difficulty arising for industrial sources is the fact, that they are usually stationary. Instead of making things easier, this has the effect that phase relationships between different sound propagation paths have a very pronounced influence on the overall result. Much more care is therefore needed in the calculations and in the interpretation of any measurement results, in addition to all the parameters usually taken into account for moving sources.

ACOUSTICAL CONSIDERATIONS

The acoustical part of a model consists of the algorithms for sound propagation between one source position and one receiver position. The signal level of the source and the source spectrum serve as primary elements. Some models use octave band spectra, or in extreme simplifications even only one octave band. A more comprehensive approach can be based on one-third-octave band spectra, as they are most common today in all noise source measurements. As mentioned above, several source types require the introduction of directivity information. This is already quite demanding for a model, since the relative angles between a source and a receiver, as well as the usually frequency-dependent extent of radiation directivity become part of the source description.

The effect of the distance between the source and the receiver is based on geometric attenuation. Attenuation in air depends on mean temperature and humidity, and is also fairly easy to include. Considerable difficulties still exist today for evaluating multiple sound propagation paths. The most important one is due to reflections from the ground. Whereas cases with simple geometry and fairly uniform ground impedance have been studied experimentally and theoretically with success, the real world cases are usually not so convenient. For this reason models often use simpler approaches with empirical relationships. As long as the sound source is a moving one, this approach is well justified, and it leads to very good results. For stationary sources some further development of the calculation methods is still needed, especially for uneven ground surfaces. The effect of vegetation in all its forms has turned out to be best treated in direct relation to the ground impedance conditions, rather than as a separate item.

Barriers are usually evaluated by considering their shape and position within a plane section that contains both the source and the receiver position. The simplest method uses only vertical plane sections. By introducing tilted planes some cases with barriers of limited lateral extent can be treated more accuratly. In the calçulation of outdoor noise propagation it has become a rule to limit the attenuation attributed to a barrier to no more than 20 to 24 decibels, in order to avoid pitfalls due to reduced barrier performance caused by wind and temperature gradients. Unfortunately our knowledge on the last-mentioned influences is not yet sufficient to allow the introduction of characteristic parameters in general applications.

In many cases the sound paths contained in a plane that includes the source and the receiver are not sufficient to describe the resulting noise immission. This happens as soon as secondary paths with one or several reflecting surfaces allow the transmission of a significant amount of acoustic power. In addition to the considerations mentioned above, the size, position, location and reflection properties of each reflecting surface need to be considered. The most important applications are found where a direct sound propagation path includes substantial barrier attenuation, whereas the secondary paths contain reflections but no barrier.

In general, the models used today include all the acoustical considerations mentioned above with a degree of accuracy that is sufficient for their practical application.

INPUT DATA

In order to allow the calculation of specified acoustic propagation paths, a number of parameters must be introduced into each model. Great care is needed in describing the topography of the area with the noise source and the receiver. This is particularly true, if the landscape is not flat, and if houses or berms, and perhaps a winding traffic path cause even the noise propagation path with least attenuation not to be easily recognizable. In one model, all topographical elements are reduced to a consistent set of prisms with arbitrary cross-sections and vertical axes, such that the landscape looks like a set of terraces.

A terrain section using a vertical plane would then always contain an approximation with vertical and horizontal segments only.

Considerably more liberty is provided with a model using a representation for topography consisting of plane, triangular surface segments. If the size of the triangles is not fixed, any topography can be described with high accuracy. The same result can be achieved somewhat more easily, if the basic element of input is a straight line segment connecting two points in space. Each point is consistently chosen to lie on the surface of the ground, and the segments are made into consecutive strings as required. They can follow contours of equal height, or the edge of a road, or even the outline of any berm, wall or building. This last approach is sometimes called a wire model. The Swiss model 77 uses this kind of terrain description, and allows several secondary data sets to be generated. With reference to any line consisting of a series of straight-line segments it is possible to specify a parallel line (edge of a road or path), or a wall or berm with triangular cross-section. If the line used as reference represents the axis of a traffic path (road, railway), then the lateral slant (camber) can be included automatically in the calculation of secondary elements. Traffic data are based on spectra in one-third-octave bands, and use a sophisticated directivity specification and simple overall level and traffic volume definitions that are directly accessible to the user.

DATA CHECKING

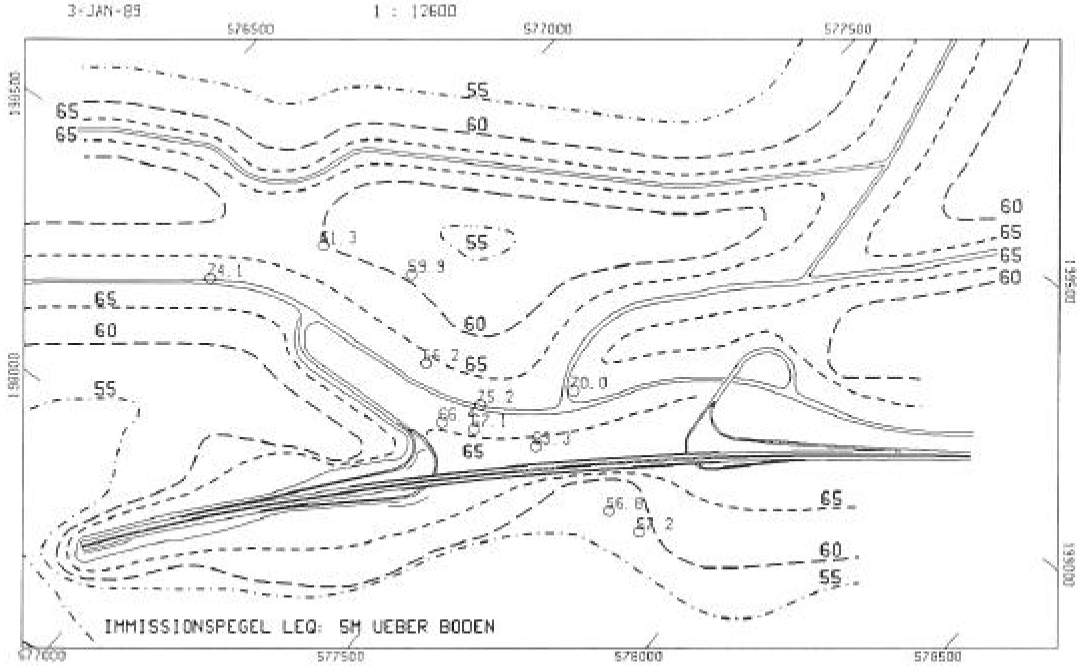
The most important task before letting any computer start extended calculations is to make sure it has error-free input data. The checks that have prooved to be most useful are plots of longitudinal sections of each traffic path, and plans with a detailed representation of each part of the topographical area concerned. They include all terrain segments and lines. The vertical coordinate z is efficiently checked even for a great number of terrain points by drawing perspective views of the topographical data used, since these correspond exactly to a visual inspection of the real area itself.

CALCULATION RESULTS

In the simplest case all the information wanted concerns a single receiver point in one given location. Even there it is usual to use not only the overall immission level Leq, but also the partial level due to each type of source, such as motor cars and lorries, or contributions due to each direction of travel on the traffic path. In all cases the maximum sound level Lmax encountered during the passage of a single source, and the location of that source when it produces this highest level is defined. If the results are drawn into a plan, both the point for Lmax and the points for Lmax-3dB on either side can be marked in order to show where the most important part of the overall noise impact comes from.

If the task includes the determination of suitable protective measures, then a diagram giving the complete curve of the instantaneous noise level as a function of the position of a single sound source is most useful. Depending on the amount of additional noise attenuation required, it is immediatly possible to make proposals for location, length and height of barriers or berms, and to test and optimize their effectiveness in subsequent calculations of the same kind.

As soon as several receiver points are involved, it is best to show the results graphically in a plan. The group of points can either be defined by the locations of existing or planned buildings, or by some suitable pattern. A very useful way of getting an overall view of the noise situation is by automatically determining a line of equal immission level Leq for a given height H above the ground. The computer can then work in predefined steps along a traffic path, and adjust the distance between the path and the receiver in such a way, that the resulting Leq level for a given traffic condition is equal to 60 dB(A) or another chosen level. The traffic condition can even include more than one traffic path. In the example given below, the results of a noise impact analysis are shown in graphic form. Contours of equal level Leq for 55 dB(A), 60 dB(A) and 65 dB(A) were determined for the superposition of a planned section of motorway together with access lanes, and all the existing roads with the traffic they will carry after the motorway has been built. The contours were determined for a receiver height of 5m above the ground. They are of rather a complicated shape, because the terrain includes several hills, and the center part of this motorway section is a bridge with solid side walls for noise protection. Since the immission levels for all existing buildings were of particular interest, they were included in the diagram with their numerical values at the appropriate locations.



For the special case where a community authority wishes to know, how high new buildings may be built behind some natural or artificial barrier, without a specified limit for the immission level being exceeded, the same procedure has been programmed for curves of equal Leq in the plane at right angles to the traffic path.

CONCLUSIONS

Several calculation models for noise propagation have been in use for more than 10 years, and have been applied to a great number of projects. This experience has led to numerous additions and facilities to take care of special requests, and to make the models more universally and more easily applicable. It has been a consistent policy to include the recalculation of some measured noise data wherever possible. The results of these comparisons have been very good. We now have good models with sophisticated input and output facilities, and we are ready to implement even better acoustical algorithms when they become available, especially for stationary sources.