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COMPUTER PREDICTION MODELS AND THE SYSTEMATICS OF DETERMINATION OF THE NOISE PROPAGATION PATHS

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ABSTRACT
Noise prediction models for road traffic and for railway noise consist of the calculation of noise propagation from a line source to a receiver point. Some prediction models make this calculation with a pure line source, but most of the models calculate with a large number of small point sources representing this line source. A variety of systematics and definitions are used. Examples are: line source models, 2D models, 3D models, ray tracing or semi ray tracing, pyramid tracing, etc. This paper gives some considerations at the systematic of the determination of these propagation paths. In addition, propagation paths with reflections will be discussed.

1 - INTRODUCTION
Calculations to determine the equivalent noise level of environmental noise on a large number of points are done by a generic noise prediction model. In addition, the calculation of noise contours or noise mapping need a large amount of receiver points or a grid of points where interpolations are made. Therefore, we need the results on single points. For industrial noise most of the situations we will start from single point source but road traffic and for railway noise we are forced to start from a line source. A road or a railroad is represented as a line source with an equal spaced sound power level.
Generic noise prediction models consist of two main parts: the model with the source description and the models with a description of the noise propagations from source to receiver. The propagation models can be divided into line source models and point source models. A line source model calculates directly the propagation attenuation based on a cylindrical spreading and the view angle from receiver to the source line. The point source models are the more evaluated noise prediction models, which use a general propagation model with a description of the attenuation factors for a single source to a single receiver point.
Most of the time the referring calculation models are based on theoretical and empirical formulas. Sometimes, where prediction models might have reached their limits of application, more advanced numerical techniques, as boundary element, finite elements or parabolic equations will be used. These techniques are only applicable for very small areas and require an enormous calculation time on a computer. But also, for these more advanced numerical techniques a propagation path, special the source position, must be defined.

2 - LINE SOURCE VERSUS POINT SOURCE
A road or railroad can be represented in two different ways. The first is the use of the source as a line source and evaluate the propagation effects starting from the perpendicular distance between the line source and the receiver. Since the propagation from the line source to the receiver has to be the same over the whole area, this method is not common in most cases. Figure 1 gives an example.
The second method is to split up the line source into segments. This is shown in figure 2. These segments are represented acoustically by point sources, for each of which the propagation to the receiver

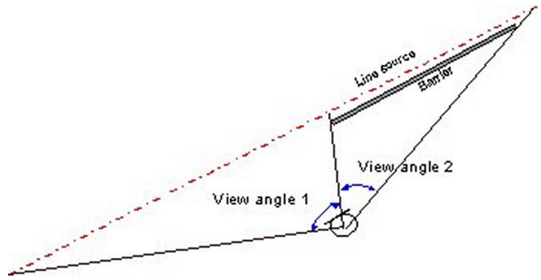

Figure 1: An example with the calculation with a line source with two different view angles with a different propagation.

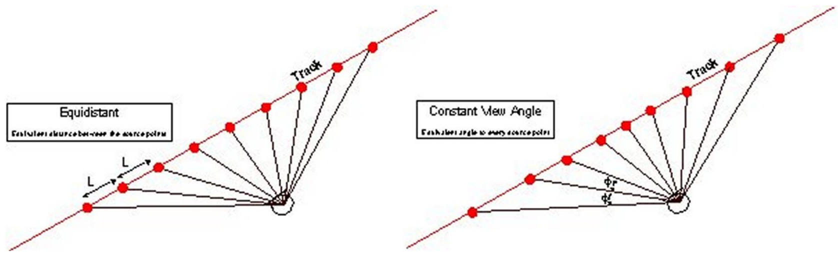

Figure 2: Two methods of division of the line source into point sources.

is evaluated separately. All contributions from the segments are aggregated to give the total sound pressure level of the line source.
For each segment, an angle of sight Φ can be defined. As shown by figure 3, where $l_{segment}$ is the length of the segment, R is the distance from the point source to the receiver and φ is the angle between R and R_p.

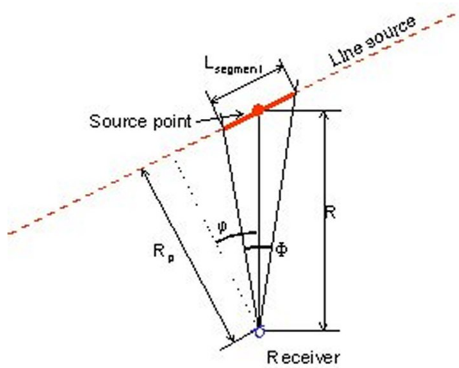

Figure 3: Division of the line source into segments.

For some prediction schemes the angles φ and Φ are situated in the plane through the line source and the receiver. This plane is horizontal only in cases where no height differences between the line source and the receiver occur. In most practical cases, the vertical height differences are relatively small compared to the horizontal dimensions and therefore the angles φ and Φ can be determined in horizontal projection. Other prediction schemes calculate angles in the three dimensional area.

3 - DIVISION OF THE SOURCE

Three methods for the division of a line source into segments can be distinguished:

- The point sources will be equally spaced over the line source. This method is not used in traffic models because it implies either a lot of sources or a loss in accuracy.
- Division based on the angle of sight Φ. The total line source is subdivided into a finite number of segments with a certain angle of sight (from the receiver point), which is sufficiently small.

- Division based on the source segment length $l_{segment}$. The line source is subdivided into a number of segments, the length of which is determined in relation to the distance R from the point source to the receiver.

The angle and length dependent methods seem quite similar but have considerable differences, especially at the outer ends of the line source. The length dependent method will have many very small angles at both ends, contrary to the fixed angle method.

4 - THE DETERMINATION OF THE SOUND PROPAGATION PATHS FOR POINT SOURCE MODELS

Most of the noise propagation models give the propagation attenuation between a point source and a receiver point. This means that a calculation has to be carried out for a large number of source positions in which also the influence of buildings, other objects, ground absorption and surface height is incorporated.
There are two methods of determination of the sound propagation path in relations to these other relevant information:

- The view angle or better the sector angle seen from the receiver will be equally spaced. Some models use a constant sector angle of 1°, 2°, 5 or 10°.
- Division based on all the objects and other input information. The angle of all these sectors will be calculated on the (corner) points or on all the nodes of all the input data.

In figure 4 these two methods are roughly drawn.

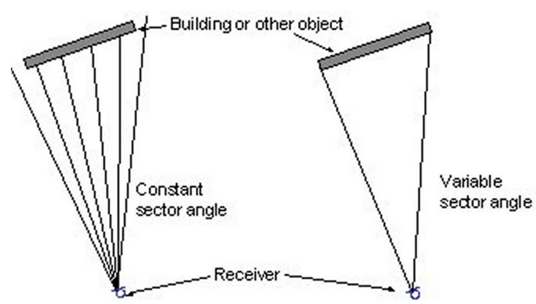

Figure 4: The two calculation methods in relation to other relevant data.

The method with the constant sector angles has, at the first impression, an important negative aspect. At a certain sector angle (parts of a) building and other objects can be missed in the propagation calculation. This will never happen in the method with the variable sector angle. For the method with the constant sector angle a very small angle is need to be used. There is one other aspect, which is relevant. This aspect is the amount of calculation paths. For large computer simulation models, the method with the variable sector angles will calculate an enormous amount of sector angles. First, this has to do with the calculation time but also with accuracy and the relevance of the input data. We all know that the acoustical relevance of small buildings and objects on a somewhat larger distance from the source and from the receiver is almost zero. A small shelter on the other site of a road has no significant contribution to the noise level due to this reflection. In figure 5 these two methods in relation to small buildings en objects are roughly drawn.
Both methods come close to each other if the method with the variable sector angle gets a minimum and a maximum sector angle and the method with the constant sector angles has a small angle. Figure 6 gives an impression of the calculation path (without reflections) with methods with a constant sector angles. As we know for the complete view from a façade of a building, we get 90 sound paths with a sector angle of 2°.

5 - PROPAGATION PATHS AND REFLECTIONS

The method for calculating reflections is very straightforward. Most of the models use an imaginary receiver point (or an imaginary point source, which is basically the same principle). This imaginary receiver point is determined by using a mirror at the plane of the reflecting surface. The prediction model defines the conditions for the reflection. For example, the reflecting plane should have a certain size, in relation to the wavelength and a certain height. There might be also conditions for the vertical

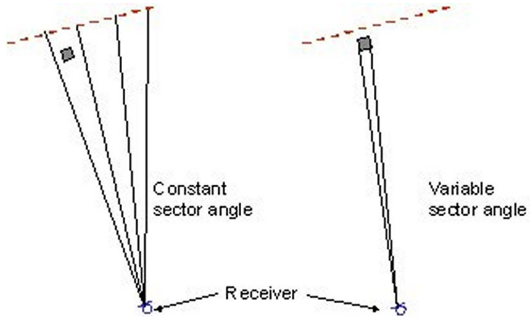

Figure 5: The two calculation methods in relation to other not acoustical relevant data.

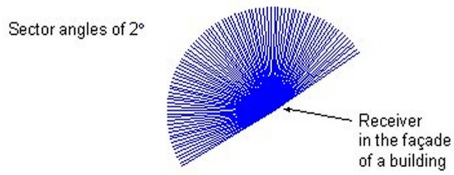

Figure 6: An example of the 90 calculation paths for the method with a constant sector angle.

angle in relation to an object purely perpendicular to the earth surface. Some models can incorporate the significant view angle, seen form the receiver or incorporate a curved sound ray. With the calculation of the reflective sound ray, of course the same attenuation factors (for example barrier attenuation) will be taken info account.

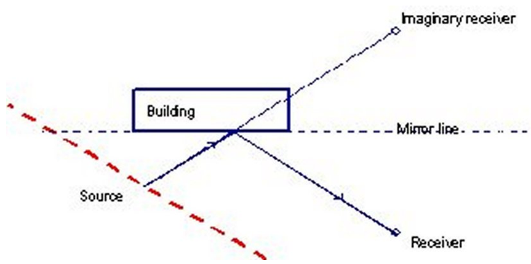

Figure 7: The method of calculating reflections.

For multiple reflections, the same method is used sequentially. For every reflection, a decrease of the sound level is taken into account. This decrease of the sound level is dependent on the reflection coefficient of the reflecting facade. In practice, it has been clear that calculations with multiple reflections will not give more accurate results, in relation to calculations with one reflection (per sector).
The calculation of the propagation attenuation of a reflection path has an extra reduction because of the reflection. This reduction, as defined in some prediction models, is a fixed value for the complete frequency range. In practice, we have a large range of different facades, varying from a flat closes wall to a highly irregular surface with windows, balconies etc. Therefore the energy of the reflective sound wave is not well defined and most of the times affected by scattering.
One other issue is that for a full reflection you need a certain area of the reflecting plane. This surface has to be at least the size of a wavelength. A reflection on small objects is not relevant. Some prediction models can even calculate a reflection on a lamppost (assuming these objects are fed into a computer simulation model. With the automatic connection of all kind of data files it is increasingly the case that small acoustically not relevant objects are imported in this computer simulation model). In addition, the edge of a reflecting plane will introduce a scattering effect, which is not incorporated in prediction models.
As described above, a propagation path including a reflection is determined with the use of an imaginary receiver. For the calculation, the sound path will be a straight line. In some prediction models, the sound path is defined as a curved sound ray. This is due to the background that most of the prediction models calculate the sound level for a down wind situation. For models, which calculate by a straight

line, we will get more reflection paths in relation to the definition of the paths with a curved ray.
In practice there is one other aspect. The calculations are always done for the down wind situation. Because the calculations are made with the use of an imaginary receiver, this means that the wind will blow in the direction towards the reflecting façade but also from this façade.
Some prediction models are not able to calculate with more than one barrier or other screening objects. In a situation of a sound path with reflection crosses more than one barrier or object, only one of these objects will be used for the calculation of the barrier attenuation.

6 - CONCLUSIONS AND SUMMARY

A road or railroad can be calculated in two different ways. These methods are based on a line source or on a split up of the line source into point sources.
The division of the source can distinguish the point source models. There are three methods for the division of a road or railroad into segments: equally spaced, on the angle of sight and on the source segment length.
There are two methods of determination of the sound propagation path in relation to other relevant information: a constant sector angle of 1°, 2°, 5 or 10° or a viable sector angle base on the nodes of all the input data. The acoustical relevance of the input data has to be considered in relation to accuracy and calculation time.
The propagation paths in relation to reflections need special care and even more care for the calculation of multiple reflections. Relevant aspects are different kind of facades, a certain size of the reflecting plane, a curved ray, wind directions and multiple barrier attenuation. Most of the situations can be calculated with one reflection (per sector).

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