HARMONOISE: NOISE PREDICTIONS AND THE NEW EUROPEAN HARMONISED PREDICTION MODEL

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1 INTRODUCTION

The assessment and management of environmental noise has become a hot issue. This has become even more the case since the European Commission issued a directive on noise [1]. The noise directive describes what to do when developing a noise policy. This first action is to investigate the existing situation. Noise annoyance or noise levels need to be quantified. Taking measurements would seem to be a logical way of doing this. Such measurements appear to be more straightforward than calculations in the eyes of the public. Nevertheless, in most member states the standardized methods state a general preference for calculation as the way to assess environmental noise levels.

At this moment in Europe, there is a lack of harmonised methods of sufficient accuracy for the prediction and assessment of noise from roads, railways and industrial sites. The available national methods have been compared and evaluated. Literature [2, 3, 4, 5] gives some results. The conclusion of the evaluation of the European Commission's noise steering group was that none of the available methods was sufficient to satisfy the requirements of the directive.

The conclusion is that a new prediction method should be developed. This new method will become obligatory for the authorities and specialised consultants in all European Member States. The range of application will be wide: the assessment of environmental noise levels for permit application, urban planning, mapping and zoning, noise abatement action plans and for predicting noise levels in future situations. These application purposes can be summarised by the common term: environmental noise management.

The main objective of the Harmonoise Project is to provide new prediction methods for environmental noise from roads and railways to meet the requirements of the EC directive in that they are more accurate, more reliable and, on that basis, enjoy general international acceptance by future users throughout Europe.

2 STRUCTURE OF THE HARMONOISE PROJECT

The project is divided into several work packages. Work package 1 relates to the noise sources, with a distinction between road vehicles and rail vehicles as sources. In work package 1.1 the noise sources from moving road traffic vehicles are considered. The same is done in work package 1.2 for railway sources. All the sources are described as physical noise sources with a total sound power, directivity and a certain position.

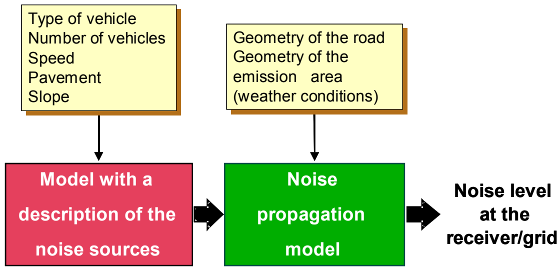

Figure 1- The distinction between noise sources and propagation

An important objective of work package 2 is to develop a “Golden Standard”. This standard is a prediction model based on advanced techniques such as the Linearised Euler model, the Parabolic Equation Model, the Fast Field Program, the Boundary Element Method (BEM), Meteo–BEM, a ray model with straight and curved rays and the Gaussian Beam Model. With this reference model, a limited number of situations are calculated to get information on the point-to-point noise propagation.
The noise attenuation from source to receiver must be a function of geographical information in the cross-section between source and receiver, such as the source height, ground surface impedance, ground altitude variations in this cross-section, barriers and buildings. This attenuation must also be a function of meteorological conditions, determined by wind speed and air temperature gradients for each specific direction. Figure 2 shows some examples of propagation paths. From the line where the noise is emitted is divided into a number of point sources. From all these sources, the acoustical energy is transmitted to a receiver. It should be clear that the figure does not give every propagation path.

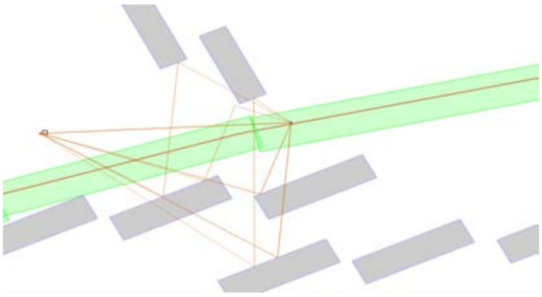

Figure 2 - Some examples of propagation paths.

It is along these paths that the sound propagation should be calculated. Defining these sound propagation paths is the only feasible method of predicting noise levels in complex situations. The main task of work package 3 is to combine the acoustical propagation paths with the point-to-point propagation and the noise sources. The result is an engineering model. Another important point in this task is to simplify the calculation method so that it becomes acceptable for practical use. For example it is impracticable to measure the ground impedance of every single square metre of a city and it is also not realistic to model small variations in asphalt surface.
Work package 4 deals with the validation of the reference model and the engineering model and of some of the individual components of the source description and the propagation. The main object of this work package is to collect data from measurements.
The other work packages deal with dissemination, exploitation, co-ordination and project management. More information can be found at the Harmonoise side [6].

3 THE ROAD AND RAILWAY SOURCE MODEL

In road and railway source modelling, one can distinguish vehicle models from traffic models. The outcome of work packages 1.1 and 1.2 is considered to be a vehicle model, describing the sound power output of a single moving vehicle, distinguishing different physical mechanisms such as rolling noise, traction noise and aerodynamic noise. Figure 3 shows a moving vehicle, passing over a road segment with length L.

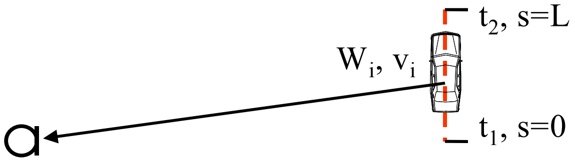

Figure 3 –The sound exposure from a moving source

Using $v_i(t) = ds_i/dt$, the sound exposure caused by a passing vehicle with sound power W_i can either be defined as a time integral or as a spatial integral [7]:

$$SEL_i = 10\lg \int_{t_1}^{t_2} \frac{W_i(t)}{W_0} A(t)\, dt = 10\lg \int_0^L \frac{W_i(s)}{W_0} A(s) \frac{ds}{v_i(s)} \quad (1)$$

where A is the total of all attenuation effects and L is the road segment length.

If we consider N events during a time interval T, road segment's contribution to the equivalent sound pressure level is given by:

$$L_{eq} = 10\lg \int_0^L \left(\frac{1}{T} \sum_{i=1}^{N} \frac{W_i(s)}{W_0 v_i(s)} \right) A(s)\, ds \quad (2)$$

In the integrated engineering method, the sound power of individual vehicles W_i in the vehicle model are combined into a traffic model yielding the equivalent sound power output W'(s) of a traffic flow consisting of N vehicles per unit time.

$$W'(s) = \frac{1}{T} \sum_{i=1}^{N} \frac{W_i(s)}{v_i(s)}$$
$$L_{eq} = 10\lg \int_0^L \frac{W'(s)}{W_0} A(s)\, ds \quad (3)$$

The traffic model deals with the fact that on a certain road/railway-section, individual vehicles of different types may move at different speed and under different driving conditions. The traffic model yields the sound power for the road/railway, which is equivalent to the total noise emission of individual vehicles. Especial for urban roads (near intersections) and railways (near stations) these variations in vehicle speed and driving conditions can be significant.

For the definition of propagation paths from roads or railways, the source lines need to be split up into source segments, represented by mutually incoherent point sources. Such segmentation of noise sources can be done in several different ways, yielding different results.
The aim for the engineering method is to have an unambiguous method of source segmentation, with sufficient accuracy, but without generating an unnecessarily large number of propagation paths. A typical case to consider is when the receiver is in line with (a part of) the source. This is illustrated by the example below, where a source line is segmented by a fixed viewing angle.

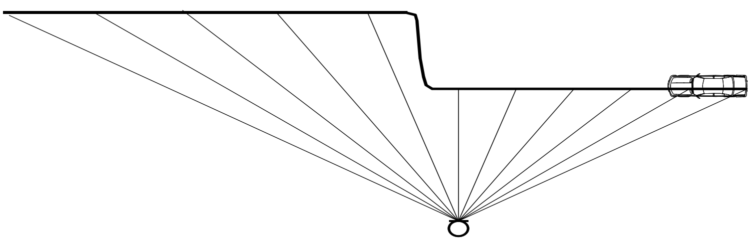

Figure 4: example of fixed angle source segmentation

Figure 4 shows that angular segmentation will lead to errors when a receiver is (approximately) in line with the source. On the other hand source segmentation by a fixed length may lead to a large number of remote point sources that have a small contribution to the total noise level. Therefore, the integrated engineering method uses a variable segment length, based on the ‘optical length’ of the source segment. This ‘optical length’ is a function of a standard viewing angle and the shortest distance between the source segment and the receiver [8].

4 THE NOISE PROPAGATION METHOD

The total noise attenuation is primarily composed of geometrical divergence, atmospheric absorption and excess attenuation. If reflected propagation paths occur, a correction is made for the effectiveness of each successive reflection.
Primarily, all computations are done by 1/3 octave, but reduction into 1/1 octave is considered an option for the reduction of computation time.

The attenuation by atmospheric absorption is computed according to ISO 9613-1 [9], with ambient temperature, ambient pressure and relative humidity as input parameters.

The computation of excess attenuation can be considered as the major ‘building block’ of the engineering method. Although it is described in detail in the paper of D. van Maercke [10], a brief outline is given in this paper as well.
For the computation of excess attenuation, the development of the Nord2000 prediction method [11] has proven to be very valuable. Several principles have been adopted from this method and some have been developed further. The method uses the model of Chien and Soroka [12] for computation of excess attenuation over flat, homogeneous ground, based on the spherical reflection coefficient Q. This principle has been extended to inhomogeneous ground by using Fresnel-weighting of contributions from different ground segments.

Diffraction effects are taken into account by the Deygout-approximation [13]. If multiple diffraction points occur, the convex hull is constructed over all diffracting edges. Secondary diffraction points below this hull are taken into account to a limited extend. Much attention has been paid to continuity of the model, e.g. in case of very low barriers on flat ground.

For convenience, the ‘curved ground-analogy’ [14] has been adopted by inverse curving of the terrain rather than curving sound rays for assessment of meteorological refraction.

5 METEOROLOGICAL MODULE

In the meteorological module, the radius of curvature is determined for each propagation path, based on wind speed, wind direction and a general description of the atmospheric stability in terms of the degree of cloud cover and the period of the day.

For assessment of the meteorological refraction, a combined linear/logarithmic sound speed profile is assumed [15]. In the relation used both the linear coefficient and the logarithmic coefficient are composed of a thermal and an aerodynamic component. There is a relation with physical quantities such as the friction velocity, temperature scale, and Monin-Obukhov length as their basic input parameters. For convenience, default values are provided for 25 combinations of wind speed and atmospheric stability.

The outcome of the meteorological module is expressed in terms of a radius of curvature for each propagation path, based on an estimation of the maximum height of the ray path [16]. Obstacles such as buildings and forests disturb the sound speed profile in open terrain. Therefore, a correction is applied to the maximum ray path height for “mesoscale” meteorological effects.

6 SOME FIRST RESULTS

Based on the described fundamentals some test software is developed. This test software is divided in two blocks. The fist block is test software with the calculation of the point-to-point attenuations for a given propagation path. Therefore, this is the attenuation of one sub source of a vehicle at one position including the reflection(s) on the ground. The second test software include this point-to-point test software but also includes the source model and the module for the determination of propagation paths without reflections and with reflections on vertical (or almost vertical) obstacles. In this software also meteorological input parameters as temperature, wind speed and direction and stability class are available.

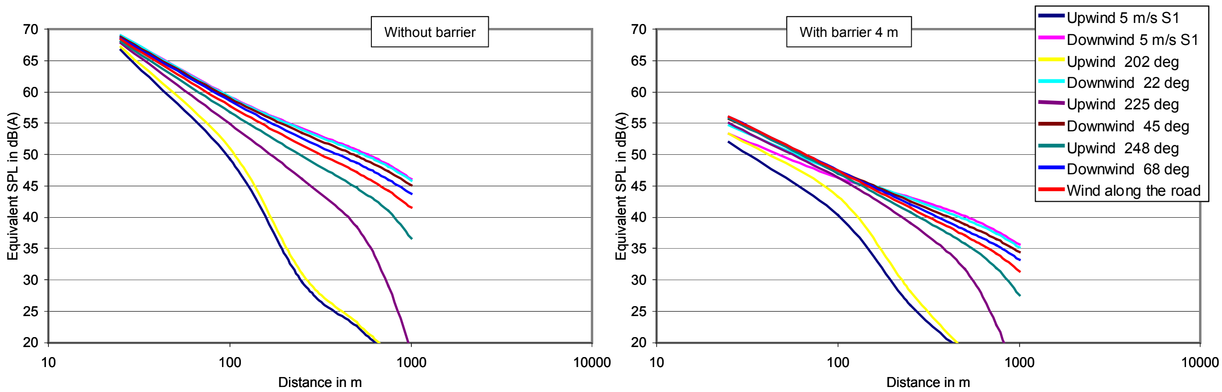

Figure 5- An example of the noise level at certain distance from the road and with different wind directions and for a situation without and with a 4 m high barrier.

An example of the calculated equivalent noise level is given in figure 5 as a function of distance from the road and with different wind directions. Figure 6 gives an example of noise maps for four different weather situations. The combination of the amount of time for every meteorological situation will give the L_{den}. This calculation has to be done for a yearly average. Some work on statistics will lead to conclusions on the number of meteorological events to be considered, depending on the required level of accuracy. An example is the question whether we need separate calculations for summer and winter situations

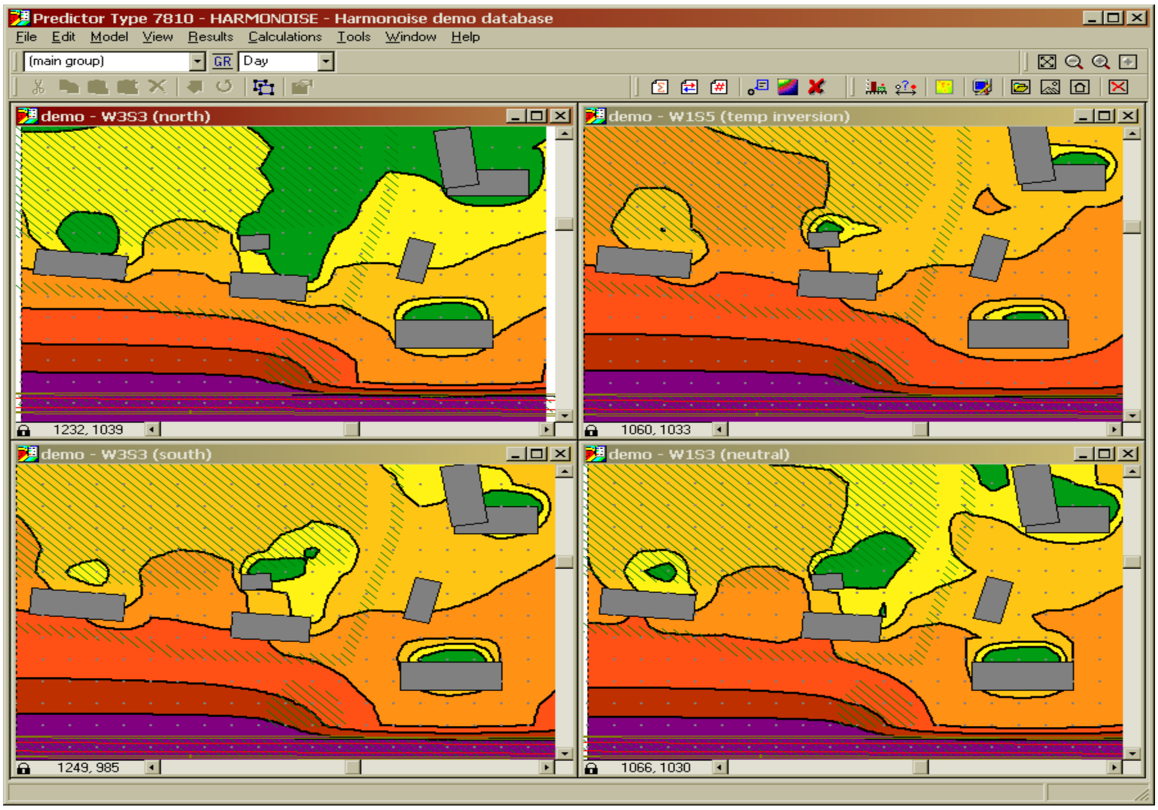

Figure 6- Examples of noise maps for four different weather situations.

7 CONCLUSION

The HARMONOISE engineering method combines the physical description of road and railway sources with a flexible and thoroughly validated propagation model. It includes a meteorological module that converts meteorological data to ray curvature. Solutions have been chosen such that discontinuities in the computed noise levels, which may occur by small changes in the geometry, are avoided.

The method is developed for both detailed studies and for large scale three-dimensional modelling. Optimisations and validations of the method are still under study, in order to increase the computation speed without unacceptable loss of accuracy.

Also under study are the requirements on the accuracy of input data. The balance between availability of input data, calculation time and accuracy of the noise levels are differentiated between the different fields of application.
Very detailed input data will result in accurate results. Less detailed input data and default values are acceptable for strategic noise maps of large areas. An intermediate level of accuracy of input data and default values must be used for assessment and for detailed noise maps.

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