The Harmonoise Engineering model

Hans van Leeuwen , Renez Nota

DGMR Consulting Engineers BV

*The Hague, Maastricht, Arnhem, Drachten, **www.dgmr.nl***

P.O. Box 82223, NL-2508 EE, The Hague, The Netherlands, Email: ln@dgmr.nl / nt@dgmr.nl

Abstract

One important deliverable of the Harmonoise project is a prediction model which can be used for noise mapping, action plans and also for calculating façade levels to check upon a noise legislation. Making noise maps and action plans are obligatory in relation to The European Directive relating to the assessment and management of Environmental Noise.

At this moment, within the complete acoustical world, there is experience with a number of prediction models, which are used in practical situations. One other point is the discussion between users and developers of scientific models and the users and developers of engineering models. It is necessary that the Harmonoise engineering model will work in practise. This means anywhere applicable, short calculation times and accurate. These aspects are diametrically opposed to each other. The last point is the discussion concerning for example traffic flow and things like the meteorological data.

Zusammenfassung

Eine wichtige Überlieferung aus dem Harmonoise Projekt ist ein Vorhersagemodell, das benutzt werden kann um Lärmkarten und Lärmminderungspläne zu erstellen und außerdem um Berechnungen an Fassaden durchzuführen, die zur Kontrolle der Lärmgesetzgebung dienen. Das Erstellen von Lärmkarten und Lärmminderungsplänen ist verpflichtend in bezug auf die Europäische Anordnung im Zusammenhang mit der Beurteilung und der Verwaltung von Umgebungslärm.

Momentan werden innerhalb der gesamten akustischen Welt mit einer Anzahl von Vorhersagemodellen Erfahrungen gesammelt, die in praktischen Situationen genutzt werden. Ein weiterer Punkt ist die Diskussion zwischen Benutzern und Entwicklern von wissenschaftlichen Modellen und den Benutzern und Entwicklern von Modellen des Ingenieurwesens. Es ist notwendig, dass das Harmonoise Technikmodell auch in der Praxis gut funktioniert. Das bedeutet eine ortsunabhängige Anwendung, kurze Berechnungszeiten und Genauigkeit. Diese Aspekte sind diametral entgegengesetzt. Der letzte Punkt ist die Diskussion im Hinblick auf Verkehrsströme und meteorologische Daten.

Introduction

The engineering model of Harmonise is the model for every day's use. This model will be used for making noise maps, for investigating the effect of action plans, for calculating façade levels and to check upon noise limits. The engineering model is the combination of source models, propagation paths and noise propagation. The propagation of acoustic energy is strongly dependent on the meteorological conditions but also the noise source of road traffic is dependent on temperature.

The work in work package 3 of the Harmonise project is mainly the development of an engineering model. From the start of the project it was the idea, that this would be done by a simplification of the source models and the reference model, or by using a database set up by the reference model. An alternative procedure is to develop a new model based on known principles.

The definition of propagation paths is the procedure from traffic flow to multiple sources; from multiple sources to a single source and from multiple paths to a single path. In the last one, the reflections on vertical, or almost vertical buildings are also included. For one propagation path, the noise attenuation is calculated by using the cross section in the vertical plane from a single point source to a receiver point.

When the first prototype of the engineering model is finished, some investigation on statistics, accuracy and the validation will be done.

Objectives and Considerations

The engineering model will be used for the calculation of L_{den} and L_{night}. This is on a yearly average operation conditions for the day, evening and night period. The idea for this moment is that the one-hour noise level is probably the shortest time period for the calculation of L_{Aeq}. The model should be used for separate calculation for several weather conditions. These are one or more favourable, a neutral and an unfavourable condition for noise propagation. Due to the fact that we have to calculate the L_{den} we have to make separate calculations for day, evening and night. The large change in temperature and wind conditions need separate calculations for, at least, summer and winter situations.

To create credibility and acceptance for the engineering model it must be possible to calculate large to very large models. The accuracy must be within 1 dB(A), standard deviation, up to 100 m, within 2 dB(A) up to 2000 m on a flat terrain and within 5 dB(A) behind hills and urban situations. This accuracy is in contrary with the requirement that the calculation time must be acceptable.

One other consideration is the scientific approach versus the engineering approach. From a scientific point of view it is possible to calculate a very accurate noise level for a given vehicle, a given driving speed, a temperature, a sound speed profile, a known ground impedance at several locations, etcetera. So if all relevant and important parameters are known very accurate, it is possible to make an accurate calculation. In practice however, wind speed and direction changes, there are more cars on the road, they are not driving on exactly the same speed, and the grass, or cornfield is growing. A practical situation calls for an engineering approach.

Source Models

Using lines of sources will do the representation of a road or a railroad. There will be more sources at some different heights above the road surface or track. The sources will represent as much as possible a physical meaning of a distinguished source. For the distribution of the sound power level of every different source, antenna measurements can be used. A fine tuning is possible with an inverse Reference model from single microphone measurements at 7.5 or 25 m. Emission level of every line of sources is dependent on traffic flow, speed, driving condition, road or track construction and other factors. Within the engineering model a horizontal and vertical directivity for every source (i.e. height) can be integrated.

For road traffic noise the lowest sources will represent tyre/road noise, the middle source(s) will represent the engine noise and exhaust of passenger cars. The highest source will represent the exhaust of trucks and perhaps some aerodynamic noise. A non-symmetrical directivity in the horizontal plane caused by the horn effect, exhaust etc can be used. The emission level of every line of sources is dependent on: vehicle categories, flow per category, speed per category, road surface, a slope, an intersection / traffic lights or other driving conditions. A point of discussion is the road surface condition. The emission is also dependent on the road temperature.

At this moment the idea for trains is to use 5 sources, like the interim EU model for trains. The lowest source will represent the rail and track, the source at the axle will represent the wheel, the sources in the middle will represent the engine noise and aerodynamic noise and the highest sources will represent the exhaust and the aerodynamic noise of the pantograph. Under investigation is a non-symmetrical directivity in the horizontal plane caused by the Doppler effect. The emission level of every line of sources is dependent on vehicle categories, number of trains per category, the speed per category, the track construction, breaking down and other driving conditions. The influence the rail roughness is under discussion.

Propagation Paths, Point-To-Point Cross-Section

Each propagation path consists of a set of coherent ray paths. A ray path can be direct, with reflections on the ground, diffracted or include any combination of these. All these rays will be calculated separately, in contrary to most of the older prediction models. For every separate propagation path, a propagation sector or an angle of view is defined as the angular sector drawn from the receiver to both ends of a source line segment. For this moment the propagation path detection method will be based on a method of projection on the source and with a further division in view angels and with a requirement to a maximum angle. This maximum propagation angle can vary between 0.1 and 15 degrees, depending on the topography and accuracy. After the investigation on statistics and accuracy a final choice of a reduction or an extension of the number of propagation paths and sector angle will be made.

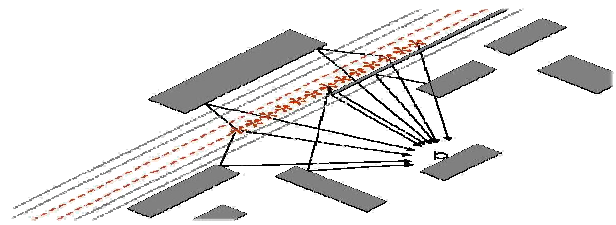

Figure 1. Some examples of propagations paths.

The point-to-point propagation is defied as the acoustical energy propagation in one cross section, or propagation path from a source point to a receiver point. The attenuation due to ground effects and barriers is the most complex part of the engineering model. The point-to-point propagation is dependent on the sound speed gradient. This sound speed gradient will be calculated from the wind speed, the wind direction in relation to the cross section direction, and the temperature profile. Of course the point-to-point propagation is depended on, the objects in the cross section, the height of the source above the ground, intersection lines with height information and the height of the receiver above the local ground level. The noise attenuation is also dependent on the ground impedance and on diffraction lines. Coherence reflection on ground surfaces will be based on the principles of Fresnel zones.

A propagation path also includes a reflection to vertical or almost vertical obstacles; in this case the attenuation is also dependent on the Fresnel zone in relation to the reflected area and the reflection coefficient.

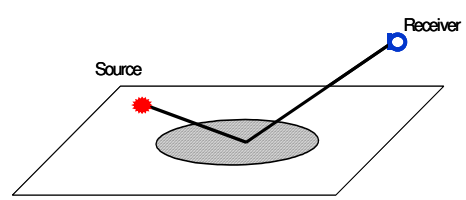

Figure 2. The principle of the Fresnel weighting.

Outline of the Engineering Model

A rough scheme of the complete engineering model is given in figure 3. This scheme gives the principles of the model. The source model, the propagation path detection method and the point-to-point propagation model is described above. Calculations will be done for certain time periods. It is defined that the shortest time period for the engineering model is one hour. So the short time L_{eq}

is for a period of one hour or longer where all the input parameters are constant. So this can be a period with wind from a certain direction, a more or less constant wind speed temperature and humidity.

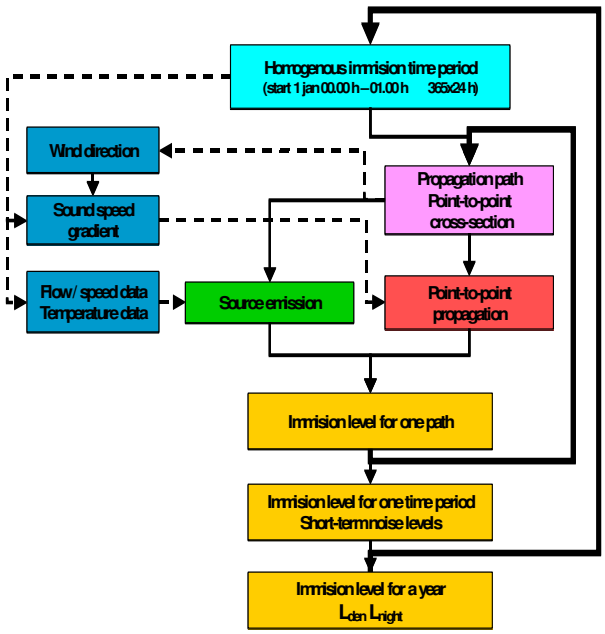

Figure 3. An outline and the principle of the complete engineering model.

The loop for the homogenous immission time periods can start at the first of January at midnight and you can start to make the first calculation. The loop with the detection of propagation paths will start and after looking complete around form the receiver, the first short term immission level is calculated. Then the second homogenous immission time period will start.

The scheme of figure 3 is a principle scheme. In computer software the sequence of the calculations might be different.

The equivalent noise level will be calculated for the day, evening and night period. An important point that is under investigation is the need of different seasons of the year. For this moment the idea is that calculations need to be done for summer and winter situations. The impression is that at least the average temperature difference between a summer day and a winter day is too large to average this effect.

For one period (day, evening or night) the equivalent noise level is equal to:

$$L_{A\,eq} = 10Lg \sum_{f=25}^{10000} \sum_{m=1}^{100\%} \sum_{pp=1}^{PP} \sum_{sp=1}^{SP} \sum_{c=1}^{C} \sum_{dc=1}^{DC} m\, 10^{\left(L_{E,f,m,pp,sp,c,dc,v} - A_{f,m,pp,sp}\right)/10}$$

where

f	1/3th octave from 25 to 10000 Hz
m	proportional time with a certain meteorological condition
pp	propagation path seen from a receiver
sp	source position and source height
c	vehicle category
dc	driving /operating condition
L_E	the emission level of a part of the (rail-)road
A	the attenuation from source to receiver

$$L_{E,f,m,pp,sp,c.dc,v} = L_{w,f,sp,c,dc,v} + D_{f,pp,sp,c,dc} + 10Lg\left(\frac{Q_{c,dc}}{v_{c,dc}}\right) + C_{f,m,sp,c,cd}$$

$$L_{w,f,sp,c.dc,v} = \alpha_{f,sp,c,dc} + \beta_{f,sp,c,dc} Lg\left(v_{c,dc}\right)$$

where

α and β	are constant values per 1/3th octave for a category of a vehicle and for a certain driving condition. These α and β values are also depended on the source height
D	the directivity in the horizontal and in the vertical plane
Q	the traffic flow in number of units per second for a certain category of vehicles and a certain driving condition
v	the running speed in m/s for a certain category of vehicles and a certain driving condition
C	a correction for other types of track constructions or road surface for a given temperature (meteorology)

One Uniform Meta Model

The engineering model is a bit ambivalent. This model will be used for noise maps and for the check upon legal limits. So for noise maps large areas are under investigation. For a check on limits only one of a few single roads and a block of houses or smaller area will be calculated. The last one needs more accuracy then a large noise map. A follow up of a noise map is an investigation with action plans. This result needs again more accuracy.

The accuracy of all the calculations will be the result of the input. For calculations over large areas for developing noise maps, the input data can be restricted to only the essential data. If no data available you can use default values. Due to the fact that the input information is limited the calculations are faster. If there is more precise data, you can use it. For variant calculations, micro scale maps, for the study of individual localised problems, and to check legal limits of building levels you need more precise input data. We have to realise that data acquisition is a difficult part and also the most expensive one. However it will be necessary to take care of the multiple use of this data. Data may be shared between different levels of use and serve different purposes.

The advantage of this approach is that only one calculation model is developed. There is no discrepancy between different models. For the development of more precise noise maps only the accuracy of input data is important. In the near future computation speed will increase so with a high detailed level of input data it will be possi-

ble to calculate in a limited time a large area. For the time being precise input data can be generalised to rougher and only relevant data to speed up calculations. On the other hand the user can use the principle from rough input data to more precise input data.

Conclusions

With the development of the engineering model the scientific approach versus the engineering approach must be considered. This is necessary to create credibility and acceptance for the engineering model. The model must be able to calculate large to very large areas but also must have high accuracy. The accuracy will be the result of the input; only the essential data for noise maps, more detailed data for variant calculations and to check legal limits.

Lines of sources at some different heights above the road surface or track will represent as much as possible a physical meaning of a distinguished source. For every separate propagation path, the point-to-point propagation will be calculated dependent on different meteorological situations. Coherence reflection on ground surfaces will deal with using the principles of Fresnel zones.

Acknowledgements

These first ideas on the Harmonoise engineering model are the results of very intensive discussions, research and experience of WP 3 of the Harmonoise team. Especially the knowledge from the existing engineering models from all over Europe, the ISO 9613, the Dutch RMV-SRM II, the French NMPB and the Scandinavian Nord 2000 was valuable. The new Harmonoise engineering model will be based on a large number of principles and background information from all these models.