VALIDATION AND CALIBRATION IN NOISE MAPPING THE MADRID STUDY

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1 INTRODUCTION

Major noise mapping activities have been started all over Europe and quality of results need to be proved to avoid the presentation of inappropriate results to the public, which would instantly provoke a political backlash. Revising digital models over and over again might asymptotically reduce input errors but will never enable us to define the deviation between calculated data and real life situation.

A noise map represents either a stationary situation with traffic input data from the past, or a predicted situation based on assumptions about the evolution in the future. It is not, therefore, representative of an actual situation with traffic modifications and special events.

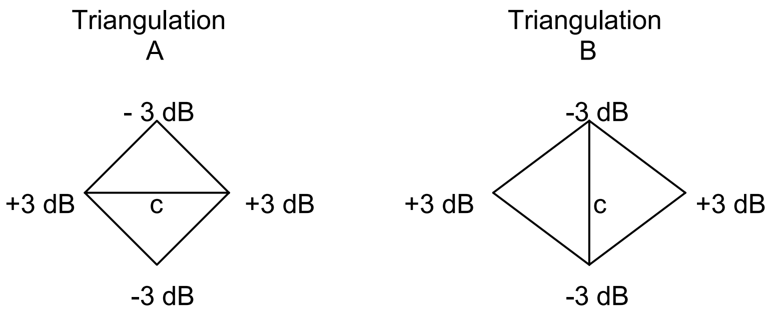
Madrid Environmental Administration decided to develop a new concept of data post-processing, that is, dynamic noise maps or SADMAM (Sistema Actualización Dinámica Mapa Acústico Madrid). Of course, it is not possible to install thousands of noise monitoring terminals all over the city, but if you know the areas of interest, then you can zoom in more precisely by installing mobile devices at strategic places. For this purpose, Madrid invested in a system comprising Lima Noise Calculation Software, together with Brüel & Kjær Noise Monitoring Software and several Noise Monitoring Terminals.

2 NOISE MAPPING AND MEASUREMENT

2.1 Calibrating an existing noise map

One idea that has been followed in the past is an adjustment of calculated noise level grids according to measurement at discrete positions.
As a general rule any large discrepancy between the calculated and measured value should result in an inspection of model and reality in the neighbourhood of the measurement.
So lets assume only deviations of +/-3 db are left and need to be cared for by adjusting a grid results. One practical approach will be to superposition a triangulated grid of correction values onto the calculated grid results. This is similar approach to the way some software handle the interpolation of digital terrain model and it will produce a similar problem:

Consider the following situation of deviations of calculation against measurement with two alternative ways of arranging the triangles.



Depending on an arbitrarily decision for triangulation A or B the noise level in the centre (c) will receive a perhaps unjustified correction of +3 or –3 dB, which may even increase the error and result in strange peaks is the noise map presentations

2.2 Calibrating sources

The example above supports the idea that measurement data should be used to calibrate sources instead of calculated grid results. There are two major categories of faults that will lead to errors in the calculated values, i.e. emission data and obstacle modelling.
Source calibration will ideally support controlling the first one, but a check of the obstacle situation in strongly advised to be done next to the measurement position.
Based on the newly defined sources levels a grid map can then be calculated that will show a good correspondence between calculated and measured values at the measurement positions and will at least produce a coherent noise map without strange peaks.

As neither the propagation model nor the calculation model will ever fully represent the reality, source calibration on systems of multiple sources and measurement positions will typically not result in a “0” deviation between calculation and measurement.

In an ideal situation the basic steps of calibrating a single line source in an ideal situation are:

- Assume an emission value for the source line
- Calculate noise level at the receiver, i.e. measurement position
- Add difference between measurement and calculated level to the source emission
- Perform final (grid) calculation, based on the new emission

So this procedure might be used to refine emission data as well as to yield emission data where no traffic count is available.

The practical situation will often be much more complex.
When trying to estimate industrial emission of a complex compound, we are not confronted with ideal source geometry but with a conglomerate of many sources. Some of them may have directivity and on the path of propagation screening and reflection will occur.
For such situations ISO describes a complex measurement procedure.

In the case of road noise geometry is more clearly structured. Perhaps separate source lines per lane should represent the source when the measuring position is next to a road. To avoid this and to position the receptor at some distance
will include effects from neighbouring roads. Other reason to stay at distance are the accessibility of

an area or the presence of local sources with regional effects only. Sometimes major ring roads and highways will be of influence though they are at larger distance. So the calibration process will have to handle multiple sources.

Directivity may be neglected when working on road traffic noise. Screening and reflection effects need to be taken into account, when thinking of measurement at some distance or of bended roads. Topography and meteorological will as well influence measurements at distance to the roads. Being able to handle barrier and reflection effects while calibrating sources will also reduce the effort and the costs for selecting such data. Think of a highway that is embedded in barriers on both sides of the road over long distances or of measurement positions on bridges.

Wherever there is knowledge about road emission available, either from previous measurements or from traffic counts, these sources need not to be calibrated any more, but we need to include them into the model to define the background noise.

Results can be improved furthermore when known relations in emission are regarded.
Such relations exist, where there is no knowledge of the traffic volume, but relative changes of emission for different sections of the road are known, due to changes in road surface or speed.

To summarise the demands on calibration tools, any attempt to do road noise calibration on a larger scale will have to handle:

- Multiple sources
- Barriers
- Reflections
- Topography
- Meteorological effects
- Background noise sources
- Relative changes in source levels

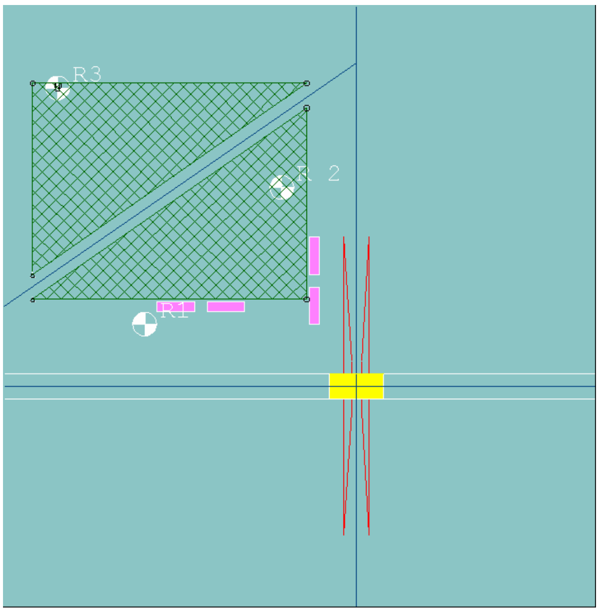
Not all regulations are of the same use for calibration sources. Using properly mirrored sources and obstacles for reflection will be important. Regulations such as ISO 9613 or the French NMPB will fulfil this condition. The source segmentation logic should not yield in any jumps in results, caused by a minor shift in receiver positions. The “method of projection” of segmentation offers the best way to ensure this.

Computing of the source calibration will try to vary the emissions of the unknown sources to minimise the deviation between calculated and measured values. We suggest looking at the total error, which can either be defined as sum of all absolute values of differences, sum of square differences or sum of energetic differences. The later is preferred as high measurement values are most likely more reliable than low values.

3 AN EXAMPLE CASE

It would be better to use an example that was based on “measurements” rather than adding an extra complication of a noise barrier.

The fig on the right shows a section of an example that will illustrate the procedure, done using the NMPB method. The “measurement” data in this theoretical example has been generated by a pre-calculation, based on assumed traffic data.



The horizontal road is a highway with known traffic data, i.e. known emission.
This will produce a background level.
Barriers of a height of 6 m are screening the highway, but there are no barriers on the bridge.
There is some major traffic on the vertical road that runs underneath the bridge and there is less traffic on the road that runs diagonal between the grassland areas (the green hatched areas).
Each of them are assigned to different emitter groups. Emitter groups assemble sources, which are subject to the same shift in initial emission value in the calibration process.

Measurement shall provide data to define emission levels for both roads.
As there are only two unknown sources, two measurement positions should be enough to solve the problem and a 3rd receptor position R3 is used to check results.
In all positions we expect significant contributions from all sources and the numerical problem cannot be separated by directly defining one source from one specific measurement.

Measurement data are:

Receptor	day (dB)	night (dB)
R1	62.3	59.7
R2	62.2	57.9
R3	56.1	53.0

The sound power level of the highway is 92.2 dB during daytime and 89.5 dB in the night.
When doing the calibrations, the two unknown sources are assumed at a level of 90 dB.
A first calibration that used measurement from position R1 and R2 results in emission data for the two other roads:

road	day (dB)	night (dB)
hori.	92.2	89.5
vert.	88.9	85.0
diag.	79.8	70.0

Receptor	day (dB)	night (dB)
R1	62.31	59.71
R2	62.19	57.90

Alternatively all 3 measurements are used in the calibration.

road	day (dB)	night (dB)
hori.	92.2	89.5
vert.	89.0	84.9
diag.	79.8	70.3

Receptor	day (dB)	night (dB)
R1	62.31	59.70
R2	62.20	57.90
R3	56.12	52.93

So the extra measurement position was not of much value in this case. The situation will change when there are hidden errors is the calculation model. A corrupt model is created by installing a barrier on the bridge.

Calibration with R1 and R2 will now result in:

road	day (dB)	night (dB)
hori.	92.2	89.5
vert.	86.8	82.1
diag.	78.8	71.6

Receptor	day (dB)	night (dB)
R1	62.30	59.70
R2	62.13	57.90

While the noise level at the two receptors is still met, the calculated emission data for the vertical road varies up to 3 dB. In worst cases of wrong modelling, receptor values will not match anymore or calibration might even fail if the background level starts to exceed the measured values.

The minor error of modelling in our case will still become more obvious, when the 3rd measurement position in introduced into the calibration:

road	day (dB)	night (dB)		Receptor	day (dB)	night (dB)
hori.	92.2	89.5		R1	62.30	59.70
vert.	86.7	79.8		R2	62.03	56.77
diag.	78.8	72.8		R3	56.67	53.17

Now we can see a deviation for position R2 of 1.13 dB.

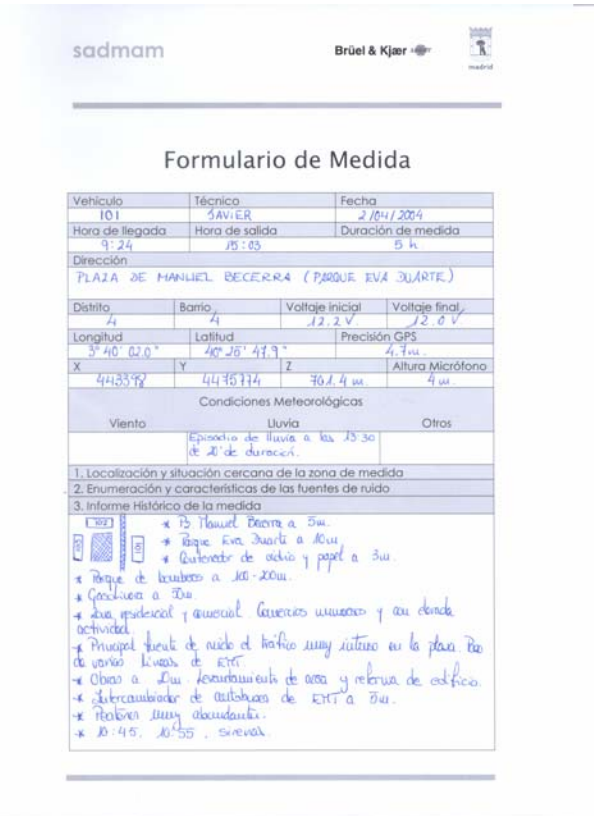
In the case of our example, the measurements could be used to define source levels and in case of redundant measurements indicate potential errors in the acoustic model.

4 THE MADRID STUDY

With its 3 000 000 inhabitants and 2500 km of streets, Madrid is an excellent example of what can be done to improve human comfort related to urban noise. Since the late 60s, Madrid City Council has been working on noise problems. Madrid's Environmental Administration runs an urban noise-monitoring network with attended and unattended noise monitoring terminals (more than 30 stationary and 16 portable). As a result, a large amount of data has been collected over 30 years. The latest noise map of Madrid was based on measurements performed from 4395 points by the National Acoustic Research Institute. Measurement data had been used to calibrate sources, as no traffic count data was available. Making use of traffic counts would also require a formula to calculate emission specific for the situation in Spain.

Sometimes measurement positions are ideal, but on other occasions diffraction or reflections of the neighbourhood need to be represented in the model.

To have a good record of the performed maesurements, protocolls are written and collected in a database.



sadmam

Brüel & Kjær

Formulario de Medida

Vehiculo	Técnico	Fecha
101	JAVIER	2/04/2004
Hora de llegada	**Hora de salida**	**Duración de medida**
9:24	15:03	5 h

Dirección
PLAZA DE MANUEL BECERRA (PARQUE EVA DUARTE)

Distrito	Barrio	Voltaje inicial	Voltaje final
4	4	12.2 V	12.0 V

Longitud	Latitud	Precisión GPS
3° 40' 02.0"	40° 25' 47.9"	4.7 m.

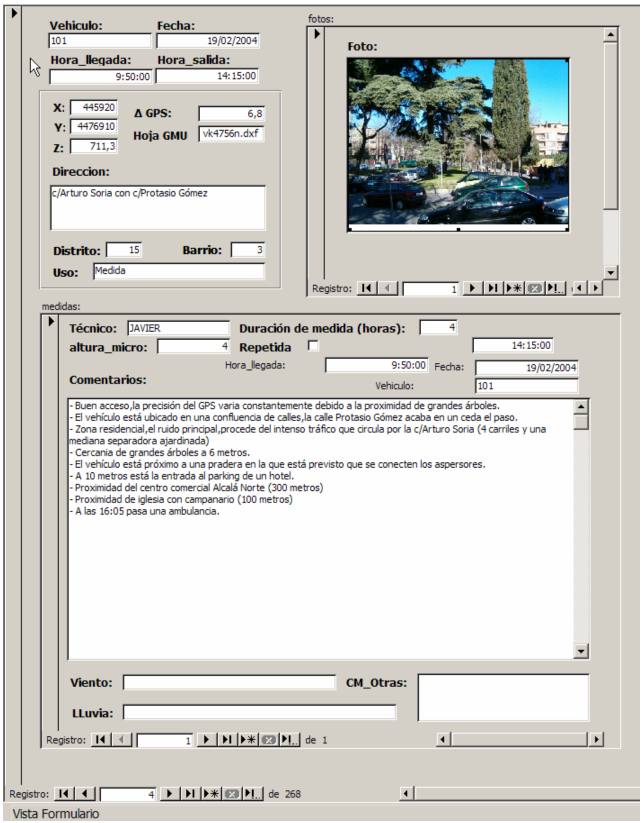
X	Y	Z	Altura Micrófono
443398	4475774	701.4 m.	4 m.

Condiciones Meteorológicas

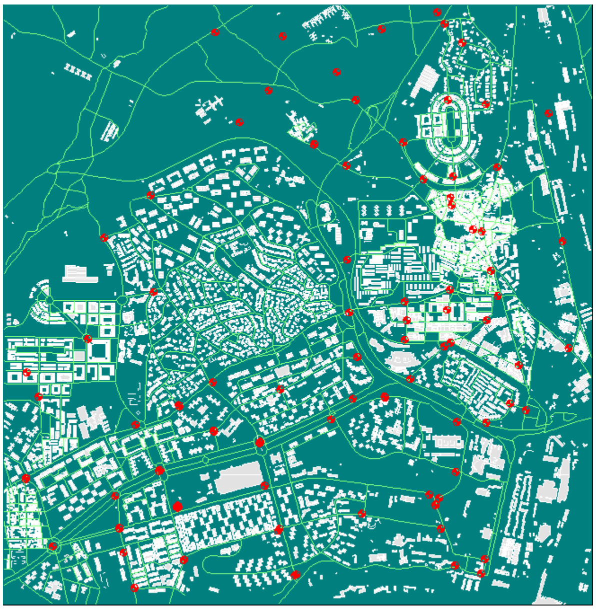
Viento	Lluvia	Otros
	Episodio de lluvia a las 13:30 de 20' de duración.	

1. Localización y situación cercana de la zona de medida
2. Enumeración y características de las fuentes de ruido
3. Informe Histórico de la medida

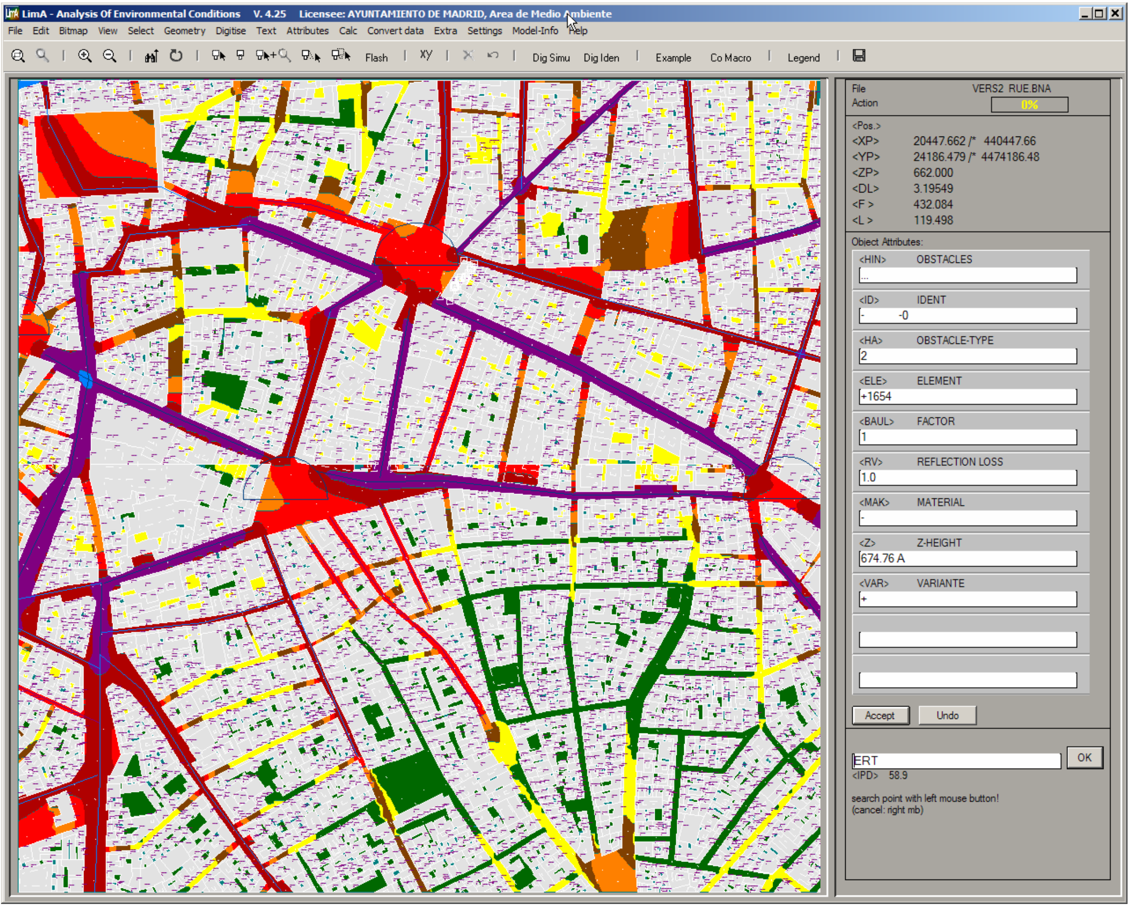
* Pº Manuel Becerra a 5m.
* Parque Eva Duarte a 10m
* Contenedor de vidrio y papel a 3m.
* Parque de bomberos a 100-200m.
* Gasolinera a 30m.
* Zona residencial y comercial. Comercios numerosos y con elevada actividad.
* Principal fuente de ruido el tráfico muy intenso en la plaza. Paso de varias líneas de EMT.
* Obras a 20m levantamiento de acera y reforma de edificio.
* Intercambiador de autobuses de EMT a 30m.
* Peatones muy abundantes.
* 10:45, 10:55, sirenas.



Measurements are collected in different places and at different times.
The red spots mark the positions used within a suburban area.



Based on the measurements the calibration of sources had been performed and at last the actual noise map can be produced.



Creating such a map is a dynamic process and new measurements at different spots will lead to refined maps.

5 CONCLUSION

Noise measurement can complement the process of calculating noise maps to ensure quality of results by adapting emission values or in some cases revealing errors in the model geometry. It can also provide means to substitute missing traffic data.

For the demand of a dynamic noise map that represents short-term development of the noise situation, it can even be seen as the favourable solution.

Thus, for example, the daily measured levels around a local road infrastructure can be used to make maps of the daily variation of the noise contours in this area.