The use of pilot areas as a base for large-scale strategic noise mapping: technical aspects and application of software-based strategies

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ABSTRACT

Nowadays, noise prediction software is the main tool for the calculation of situations oriented to predict noise in open environments. The results of such calculations support further decisions and action plans against noise in countries with a consistent legal noise control framework. Unfortunately, this approach needs to be further developed before being applied in countries with a growing economy and especially where very large cities need to be assessed. Even in the case a legal framework has been developed, there are many important technical and operational decisions to be made before a simulation tool is applied to city noise mapping over large areas. Aspects like how the available data shall be imported and simplified, the best configuration of calculations to be applied to get reliable results faster, or how a strategic noise map could be made available to the public, shall be decided by using smaller sample areas or pilot noise maps before their application to entire noise projects

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within the country. This contribution presents some examples applied to the pilot noise map of São Paulo, developed by the Associação Brasileira para a Qualidade Acustica (ProAcustica).

1 INTRODUCTION

Noise mapping has become an important tool and starting point to integrate the noise aspect in all technical and political decisions. A practical example is the implementation of the European Directive about environmental noise 2002/49/EC which bases all plans against noise on the calculation of noise maps of large areas such as complete cities and communities or even countries. This situation has pushed the development of noise prediction software packages that take advantage of the best hardware technology available.

Unfortunately, the use of noise prediction software should not be implemented directly in countries without a well-established noise regulation. First, a framework of legal requirements – such as noise limits – is needed to allow the control of any type of planning activities. The second step is the decision about the calculation methods to be used. Any calculatio method should be representative of the situation is intended to predict and therefore it should be checked by measurements. Taking the example of a parametric source like the road traffic, the comparison with measurements would help to study the behavior of the method within specific large areas. This is especially important because the resulting noise levels, which are averaged over long periods will be compared with the specified limiting values.

Last, but not least, it is obvious that even using the latest hardware and software technology, calculations could be extremely time consuming and not necessarily more accurate. Therefore, the use of acceleration techniques available in the different software packages is key to obtain reliable results faster only if the decrease in the accuracy can be estimated and therefore, controlled. This contribution discusses the impact on the calculation results of several acceleration techniques that have been tested in the pilot map of the city of São Paulo, Brazil.

2 THE PILOT NOISE MAP OF SÃO PAULO

In 2014 the Brazilian Association for the Acoustics Quality (ProAcustica) started discussions with all relevant parties about the necessity of the development of the Noise Map of the city of São Paulo. With approximately a population of 12,106,000 people, Sao Paulo is the most populated city of South America. Later in 2016, the Law 16.499 establishing the obligation for the implementation of the noise map at the Municipality of São Paulo was approved. ProAcustica founded in parallel an Environmental Acoustics Commission and a Working Group with the aim of collecting the required information to define a suitable methodology. A smaller area of the city was chosen as a base of further decisions in terms of the calculation method to be used as well as the software configuration to be applied.

Fig. 1 – 3D View of the pilot area of São Paulo

The area of the city has approximately 3 km x 3 km area, including 12852 buildings and 665 roads / streets. Several calculation methods have been tested and compared with real measurements carried out by the Working Group. The results and conclusions of the above-mentioned comparison are not part of this contribution.

3 THE UNCERTAINTY DUE TO THE SOFTWARE CONFIGURATION

The pilot area has been used to test different acceleration techniques. It must be clear that the evaluation of the influence of the software configuration in the accuracy is related to the deviation from the "exact" calculation by using the applied calculation standard. In that sense the underlying calculation method defines the "truth", and any deviation caused by the different configuration decrease the accuracy.

The approach follows the method described in the DIN 45687 which allows to evaluate the uncertainty in a noise map hat is caused by the acceleration techniques. The procedure consists of the following steps:

- The calculation must be carried over a minimum of 20 fixed receiver points which are distributed statistically over the complete area. During the tests 50 receivers have been used.
- The level at these points is calculated with a "reference configuration" where no acceleration techniques are applied. The reference configuration must be standardized beforehand, as it is the basis of the uncertainty calculation.
- Then the configuration including the acceleration techniques is applied and the calculation is repeated.
- The differences between the two calculated values are sorted out and the following statistical information is given: standard deviation, mean value and the 0.1 and the 0.9 quantiles defining the limits of the uncertainty interval according to DIN 45687.

4 CALCULATION TECHNIQUES TESTED IN THE PILOT AREA

The software strategy is critical to avoid unnecessary or not relevant calculations and therefore obtain results faster without a strong impact on the uncertainty. The selection of a certain configuration depends on the user´s experience with a specific tool as well as the type of area to be calculated. In the following paragraphs, the calculation settings under test are described.

The tests have carried out by using a reference configuration with the following relevant calculation settings:

Search Radius:	2000 m
Maximum Error:	0 dB
Projection of Line Sources:	Activated (value=1)
Max. order of reflection:	1

The calculation time (min) was: **6 m 00 s**

Then, each calculation setting has been modified and tested while keeping the others constant. The variation of the setting is done in the so-called project configurations. The last test has been carried out activating all acceleration techniques but keeping the reflection order set to 1.

According to DIN 45687, the first test placed automatically 50 receivers statistically distributed all over the area. Further tests have given results at the same positions.

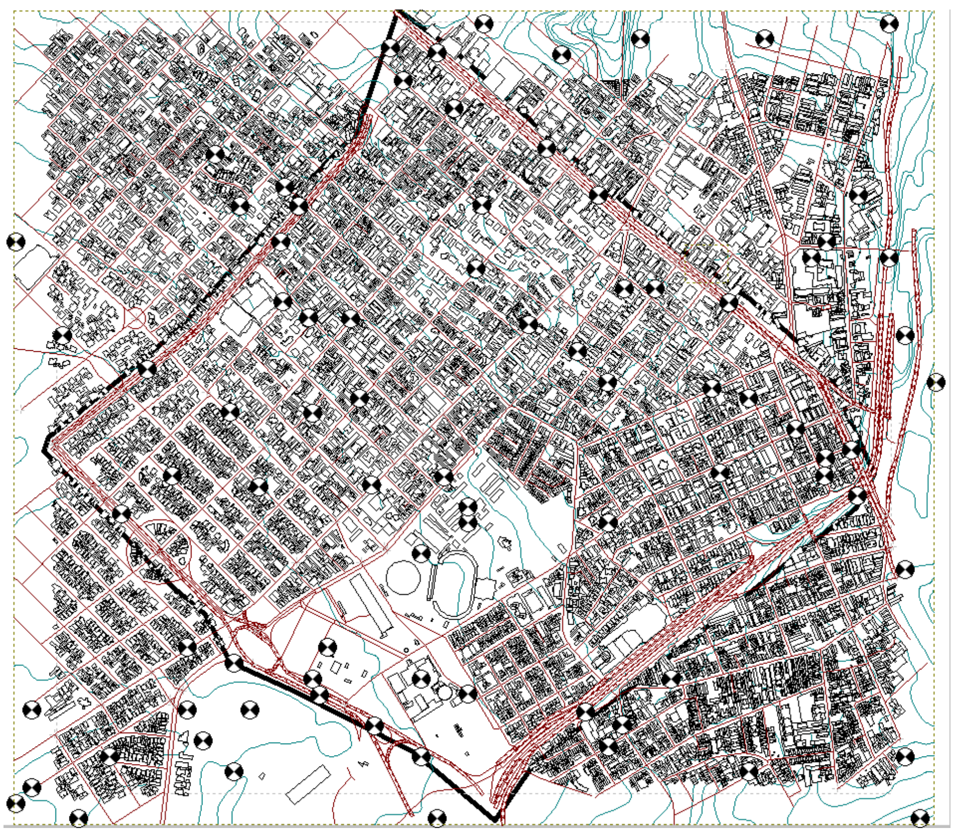

Fig. 2 – Test area and generated test receivers (50)

The relevant acceleration settings under test are explained below and the results of the tests are discussed:

2.1 Search Radius

The search radius is considered as a general calculation setting which most of the times is set to the by default value. If the level is calculated at receiver points, then the model up to this distance is taken into account and receivers out of the radius are neglected.

The reference setting is 2000 m, which is the by default configuration. The project configuration has been set the value to 1000 m.

Table 1 – Statistical analysis of the setting "Search Radius"

Calculation settings under evaluation	**Reference**	**Project**
Max. Search Radius	2000	1000
Calculation times (min):	6,00	4,69
Statistical Analysis:		
Quantil q0.1:	-0.1	
Quantil q0.9:	-0.0	
Mean:	-0.1	
Standard Deviation:	0.3	
Minimum:	-1.9	
Maximum:	0.0	

The table 1 shows the impact of decreasing the search radius to 1000 m. The statistical results of the analysis show a systematic deviation of -0.1 dB, while the Standard deviation is 0.30 dB. Applied to the pilot project the impact of the setting could be considered as low while the calculation time is 1.2 times faster.

2.2 Maximum Error

The Maximum error allows to set a value in such a way that sound sources whose contribution to the level at the receiver point is negligible will be disregarded in the calculation. Therefore, the larger the maximum permissible error in the final result is, the shorter the calculation time required. Calculating the level at a receiver is now a two-step procedure. With the first step the contribution of all sources inside the search radius is calculated neglecting all attenuations but the ones caused by geometrical dispersion. These contributions are sorted out and the real calculation is performed including the sources with descending order. After each adding up a new contribution, the sum of the contributions of the remaining rest is compared with the defined value – if it is smaller, the calculation can be stopped, because this sum of contributions of the remaining rest is related to free field propagation and their real contribution will be smaller with large probability.

The reference configuration was a maximum error of 0 – which means that the acceleration technique has not been used. In the project configuration the maximum error was set to 0.5 dB.

Table 2 – Statistical analysis of the setting "Maximum Error"

Calculation settings under evaluation	Reference	Project
Max. Error (dB)	0.0	0.5
Calculation Times (min):	6,00	3,88
Statistical Analysis:		
Quantil q0.1:	-0.2	
Quantil q0.9:	-0.0	
Mean:	-0.1	
Standard deviation:	0.1	
Minimum:	-0.2	
Maximum:	-0.0	

In this case, the analysis also shows low impact on the variation of results but a much faster calculation. This is a typical situation for noise maps in urban areas with many roads and streets considered as noise sources.

2.3 Projection

Large, extending sources, like line or area sources, are segmented into smaller sections as stated in the normative references to a size that their largest dimension is still smaller than the distance source-receiver multiplied by the raster factor. If the projection setting is activated, a pre-segmentation of this type of source occurs, depending which parts of the source are screened and unscreened and applying the distance criterion. This improve the results at receiver points especially if there are only few sources.

Table 3 – Statistical analysis of the setting "Projection"

Calculation settings under evaluation	Reference	Project
Projection Line Sources	1	0
Calculation times (min):	6,00	0,72
Statistical Analysis:		
Quantil q0.1:	-0.3	
Quantil q0.9:	0.2	
Mean:	-0.0	
Standard deviation:	0.3	
Minimum:	-0.7	
Maximum:	0.8	

With regards to this setting, the specific situation – including many sources contributing from all directions – makes the projection technique not relevant while the calculation time decreased dramatically when deactivated.

2.4 Reflection

The maximum order up to which reflections are taken into account by using image sources has a strong impact on the calculation time. In the majority of situations may be sufficient to account for 1st order reflections. Considering calculation times, it is usually recommended to use higher orders of reflection only for limited scenarios containing few objects. Besides the maximum order of reflection, additional settings and exclusions can be applied. For instance, it is possible to account only for reflectors with a definable maximal distance from source and receiver. This makes it possible to restrict reflection calculation to facades directly facing the roads or behind – seen from the source – the receiver position.

Here, a comparison between reflection orders 1 and 2 has been carried out.

Table 4 – Statistical analysis of the setting "Max. Order of Reflection"

Calculation settings under evaluation	**Reference**	**Project**
max. Order of Reflection	1	2
Calculation times (min):	6,00	53,81
Statistical Analysis:		
Quantil q0.1:	0.0	
Quantil q0.9:	2.1	
Mean:	0.6	
Standard deviation:	0.7	
Minimum:	0.0	
Maximum:	3.1	

In this case the test results show a systematic deviation of 0.6 dB which means that the values are higher with two orders of reflection. The uncertainty interval according to DIN 45687 is from 0.0 to 2.1 dB. It is remarkable the high difference in terms of calculation time. The calculation run with two orders of reflection took exponentially longer with a factor of almost x9.

5. UNCERTAINTY TEST OF THE ACCELERATION TECHNIQUES COMBINED

The last test was carried out comparing the full set of acceleration techniques activated with regards to the reference configuration. The only exception was the reflection order, which was set to first order of reflection in both cases. The final results are shown in the below table.

Table 4 – Statistical analysis of the acceleration settings combined

Calculation settings under evaluation	Reference	Project
Max. Error (dB)	0.0	0.5
Max. Search Radius	2000	1000
Projection of Line Sources	1	0
Calculation times (min):	6,00	0,36
Statistical Analysis:		
Quantil q0.1:	-0.5	
Quantil q0.9:	0.2	
Mean:	-0.2	
Standard deviation:	0.4	
Minimum:	-2.5	
Maximum:	0.8	

The combination of acceleration settings gives a very good compromise between the calculation time achieved vs the deviation of the results at the receiver points. This means that the project configuration could be a basis for further decisions before the map of Sao Paulo is calculated.

5. CONCLUSIONS

The uncertainty analysis according to DIN 45687 is a powerful method to determine the influence of acceleration techniques allowing to get the influence of accelerating settings on the accuracy and to decide about the best suited calculation configuration. It avoids unnecessary time-consuming calculation tasks while the result is perfectly suited to take decisions and design action plans.

Further steps must be considered such as the definition and standardization of the reference configuration used to calculate the values considered as “certain” as well as the investigation of the influence of the discussed and more acceleration techniques in pilot areas with a different typology within the project.

6 REFERENCES

1. CadnaA Prediction Software, DataKustik GmbH 2018
2. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise – Official Journal of the European Communities, 2008

3. Commission Directive 2015/996 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council, 2016

4. ISO 17534-1:2015 Acoustics. Software for the calculation of sound outdoors. Quality requirements and quality assurance, International Organization for Standardization

5. Acoustics – Software products for the calculation of sound propagation outdoors – Quality requirements and test methods, German Standard DIN 45687