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NOISE MAP FROM TWO COMPUTER PROGRAMS. ANALYSIS OF DIFFERENCES.

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Abstract
The European Commission Working Group *Assessment of Exposure to Noise* drew up a Position Paper with the aim to help Member States and their competent authorities undertake noise mapping and produce the associated data as required by the European Noise Directive. It was not meant to be a manual for strategic noise mapping but provided advice on specific issues that were raised initially by Member States. The Position Paper recognized that some of these issues are quite complicated and have been dealt with in detail. Really, when a unique variable is dealt with, it is not complicated to quantify its influence on the calculation but-in general- many variables are mixed up in the calculation.

Using similar configurations from two popular commercial programs, noise maps of the agglomeration of Pamplona, Spain, were obtained. Although the differences, in general, are little many improvements are needed. Detailed analyses of the differences found in the results lead us to conclude that a great precision in algorithms is needed to obtain reliable results. The most important reasons explaining such differences are a) the algorithm of visibility and b) the different implementation of the propagation under homogeneous and favourable atmospheric conditions.

Keywords: computational models, GIS, noise maps, traffic noise, urban noise prediction.

1 Introduction

The European Parliament approved the Environmental Noise Directive (END) 2002/49/CE [1] for the evaluation and management of the environmental noise. This Directive was transposed to Spanish Legislation by the Noise Law 37/2003 [2]. The objective is the prevention and reduction of the impact of acoustic pollution on the population. Establishing common assessment methods for environmental noise and setting limit values in terms of harmonised indicators for the determination of noise levels is required. According to the END, noise maps and action plans should be implemented progressively. As a result, in the last years, mathematical models and strategies for environmental noise prediction have been developed. The calculations needed to draw such a noise map using such methods are tremendously tedious, therefore making it necessary to program them on a computer. Some software applying various official models in noise mapping-both for agglomerations and for large infrastructures- began to be commercialized approximately ten years ago. It is impossible to implement theoretical methods explicitly in the calculation algorithms not only for their complexity but also for the increase in the calculation time. They simplify the algorithms attempting to obtain the best time-precision ratio. As a consequence of these simplifications, as well as their constant evolution, differences in results from programs appear.

Many countries have developed their own traffic noise prediction models [3]. For countries without their own method, the END recommends the use of the French method [4] to calculate both the source and propagation model for road traffic. This method is similar to ISO 9613-2 [5] but some of its features are more developed, such as the atmospheric propagation conditions. The NMPB considers both favourable and homogeneous conditions. Nevertheless, ISO 9613-2 only considers favourable ones. Another difference is the way of splitting up the line sources. On the one hand ISO 9613-2 describes the *Raster Factor* method and on the other NMPB also allows equiangular and variable splitting up methods.

SoundPlan [6] and Cadna/A [7] are two of the most widely used software programs in the prediction of environmental noise and they have been analysed in this report. We will refer to them as SP and CA respectively. Even though both programs implement the NMPB method, they are unable to configure all the parameters in the same way, thus giving rise to differences in the results. Examples of these variations are those caused by the source discretization method, which is implemented by angular step in SP and by the *Raster Factor* in CA. The main objective of this report is to analyse the differences found in the results of noise mapping from the results obtained from the two above-mentioned software systems.

2 Noise map of the Agglomeration of Pamplona (Spain).

The location selected to conduct the present comparative study is an area covering the city of Pamplona and its surroundings including the ring-roads. This area includes a total of 18 municipalities. Size, population and other characteristics had been detailed in a previous presentation [8]. As it could be seen, noise levels are caused mainly by road traffic so this unique source of noise will be considered to analyze differences between programs. Both the traffic flow and the average speed inserted at each and every line were provided by both the Transport Department of the Local Government of Navarre and by Navarre Motorway Company basing themselves on recorded data from 2005. The Digital Terrain Model (DTM) was uploaded by using elevation points provided by the Public Work Department of the Government of Navarre. The versions of the software programs used to draw up the strategic noise maps were CA 3.7.123 and SP 6.5.

To undertake noise mapping and provide the associated data as required by the END the European Working Group Commission *Assessment of Exposure to Noise*, WG-AEN [9] drew up a Position Paper with the aim to help Member States and their competent authorities. It was not meant to be a manual for strategic noise mapping but a source of reference for advice on specific issues that were raised initially by Member States. The Position Paper agrees that several of these issues are quite complex and have been dealt with in detail. In fact, when a sole variable is under study, quantifying its influence on the calculation is not challenging. Nevertheless many of the variables are somehow connected with the calculation.

With the purpose of comparing the findings from both programs, a receiver points set was placed on a 10 x 10 m square grid, 4 m above the ground. DTM was generated-in both programs- from the same elevation points. The initial data file consisted on a grid -5x5 meters in size- of elevation points. It was decided to simplify this data file by using the “delete height points” tool in Cadna/A based on a tolerance of 0.5 m. It is based on delete height points which do not generate changes on height greater than 0.5 m. After this simplification the total number of elevation points decreased from 15 000,000 to 600,000.

All lineal noise sources and buildings were identical for both software programs. Nevertheless, CA and SP use different criteria to adjust roads into DTM. In contrast to SP, CA generates extra points in DTM when roads are placed on the terrain. Firstly, roads were imported in CA and adjusted to DTM on account of which new extra points were generated. Secondly, roads incorporating bridges were edited to simulate them. Finally, all roads were exported from CA to SP to start from the same input data. The software programs allow to work with several configurations of the parameters. A similar configuration for both programs was used in this report (Table 1).

Table 1 – Configuration of the parameters for both programs

Parameter	SP	CA
Discretization of the sources	Angular step = 1	Raster factor = 0.5
Maximum search radius of sources	1,000 m	1,000 m
Lateral diffraction allowed	No	No
Tolerance (maximum error)	0	0
Grid interpolation	1	No
Calculate points inside buildings	No	No
Building absorption	0.21 (=0.5 dB)	0.21 (=0.5 dB)
Ground absorption	0.21	0.21
Correction limit by diffraction	25 dB	25 dB
Reflection order	1	1
Reflection depth	2	Infinite (default)
Max. search radius of reflecting surfaces	Not available	100 m
Min. dist. receiver-reflector and interpolation (for reflection)	Not available	0 m. Interpolation to 0 m.
Max. dist. source-receiver and interpolation (for reflection)	Not available	5,00 m. Interpolation from 5,00 m.

SP and CA use different methods to splitting up lineal noise sources-that is to say, roads- into equivalent point sources. The *Raster Factor* was established at 0.5, as it is the maximum value allowed by ISO 9613-2 which provides a very good time-accuracy ratio. Error in the calculation of an infinite line source is, in practice, equivalent if a *Constant Angular Step* from 1 and 2 is used [10]. SP allows to select lateral diffraction but it is not calculated because NMPB does not consider it, while CA does not calculate it whatsoever. A grid interpolation of amount 1 in SP is equivalent to no interpolation in CA. One of the most outstanding differences between programs is found on the calculation of points inside buildings. SP allows the selection of substitute points but not to eliminate points. CA allows the option to either calculate them or not. Despite choosing not to calculate points inside buildings, both programs calculated some of them but not in the same way. Due to these points are not relevant for this comparative study-they are interpolated, not calculated- and they produce high differences, it has been decided to eliminate them. The *reflected surface search radius* is only configurable in CA. A value of 500 m for *maximum distance source-receiver* parameter has been selected. The reason for selecting 0 m for *minimum distance receiver-reflector* parameter is justified to obtain the most similar configuration in both programs. The configuration of reflection depth is only possible in SP. In CA, reflection depth is infinite by default. These are the reasons why the number of reflections is not the same in both programs.

3 Results

3.1 Differences on DGM

Different algorithms have been developed to calculate the DTM. Concerning the two software programs analyzed in this report, CA presents three possible configurations whereas SP does not have any configurable parameter, and as a consequence its generated DTM is unique. This method -called *triangulation*- is based on the creation of triangular surfaces from existing contour lines and elevation points. As the triangulation method generally provides the best results, this method has been used in our present research. It is based on Delaunay's triangulation since it is a computational structure which enables researches to obtain an excellent triangulation to depict the terrain. However, the various methods to implement the algorithm in geometric computational software in order to achieve a faster and less complex method of calculation generate some differences in the results.

To compare the DTM generated by CA and SP, calculating a grid of receivers will be required as it is not possible to export the triangulation of the DTM. The analysis is based on calculating the difference at each point of the grid. In this report, an area covering the city of Pamplona and its surroundings (including the ring-road area) was used. The DTM was generated from 601,508 elevation points. The z-coordinates of points ranged from 368.37 to 1,166.44 meters. The grid was 10 x 10 meters size and the total number of points was, approximately, 1.27×10^6.

Figure 1 shows the histogram of differences (z-coordinate difference for all the 1.27×10^6 calculated points and compared one by one) grouped in ranges of 0.1 m, either positive or negative. 87.7 % of the points differs less than 0.1 m, 10.3 % differ between 0.1 and 0.5 m, 1.9 % differs between 0.5 and 1.5 m and 0.1% differs over 1.5 m. The last range is not represented in the graph.

Figure 2 shows a coloured map of differences outlining a small area that enables us to see the size of the grid and differences. The larger differences are concentrated near the boundary lines of the calculation area, especially in terrain with high gradients. With regards to this point, the most important conclusion drawn is that differences on predicted noise levels are not due (in the majority of cases) to differences obtained in the calculated DTM.

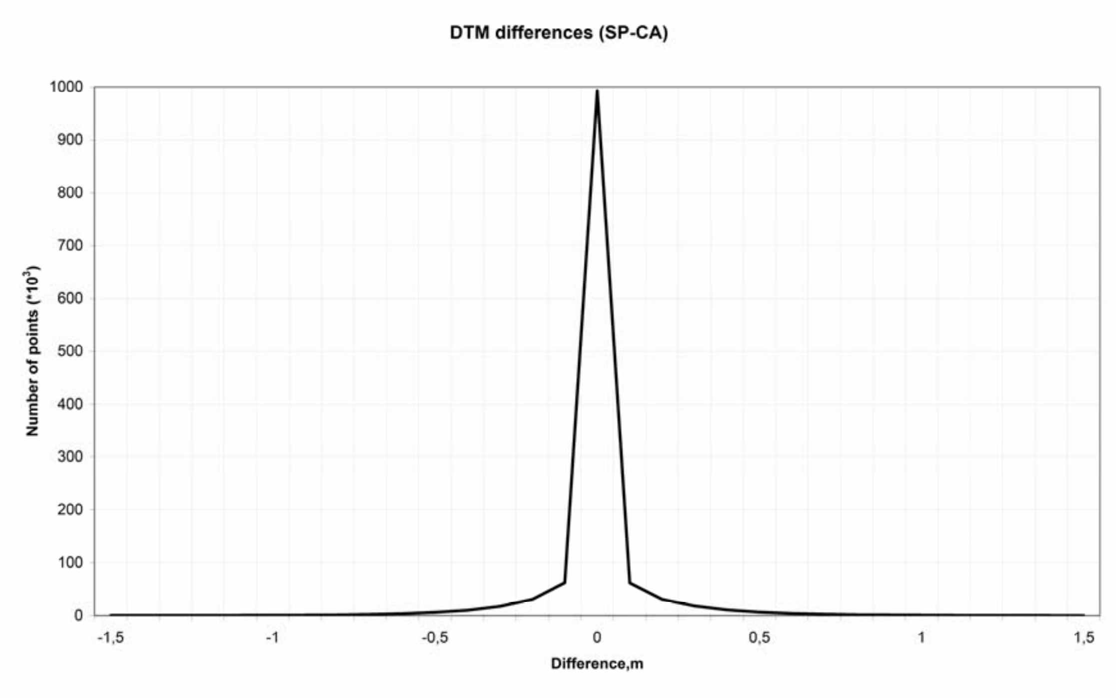

Figure 1 – Histogram of differences (z-coordinates, in m) from the two DTM generated

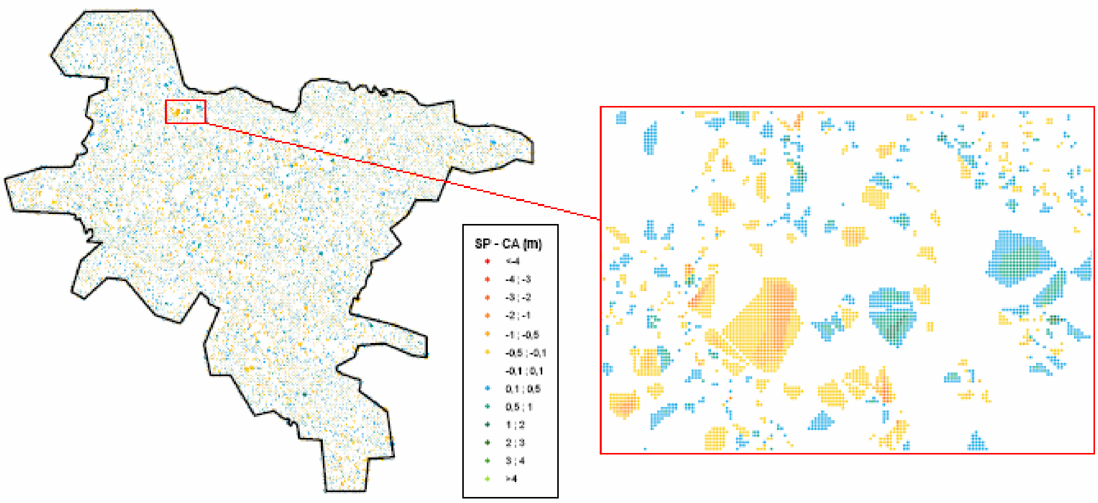

Figure 2 – Coloured map of differences from the two DTM generated

3.2 Ld and Ln differences

For the noise map of the agglomeration of Pamplona, the number of grid points calculated by each software-1.27 x 10^6, approximately, in the calculation area- varies. The main reason is that different methods are used to eliminate points inside buildings. Moreover, SP calculates some extra points in the boundary lines of the calculation area. To avoid unreal differences only the coincidental points from CA and SP have been utilized in the comparative study. Figures 3 and 4 show (again by a coloured map) the differences on Ld and Ln figures from both programs.

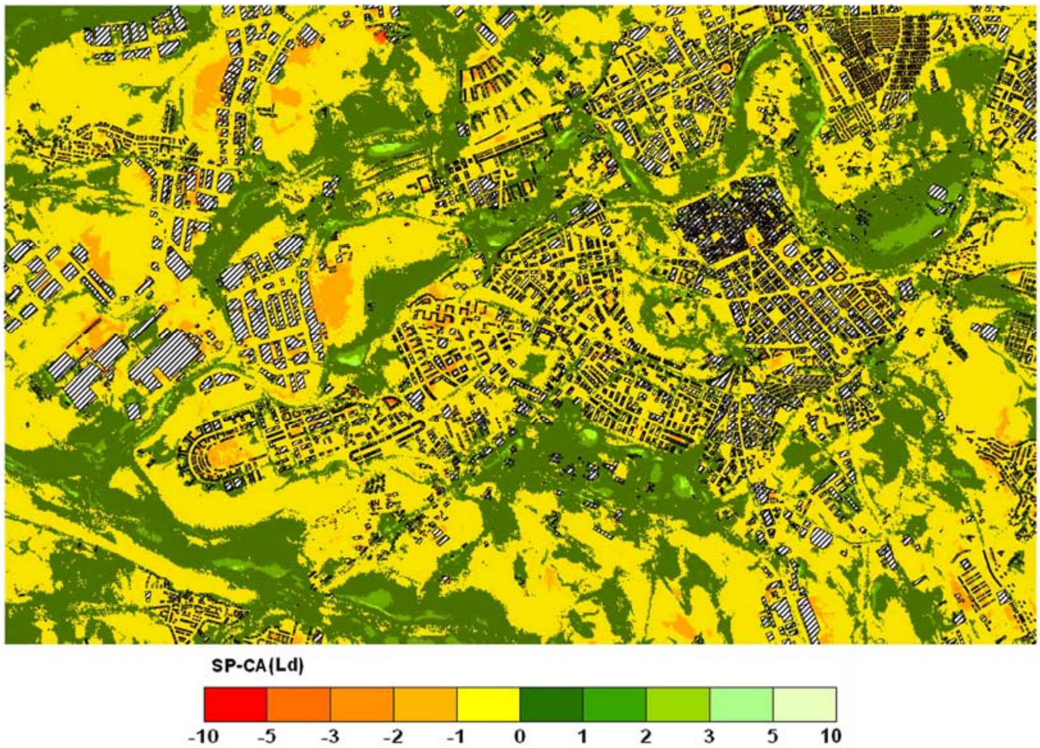

Figure 3 – Differences on Ld, in dB, from both programs (detail).

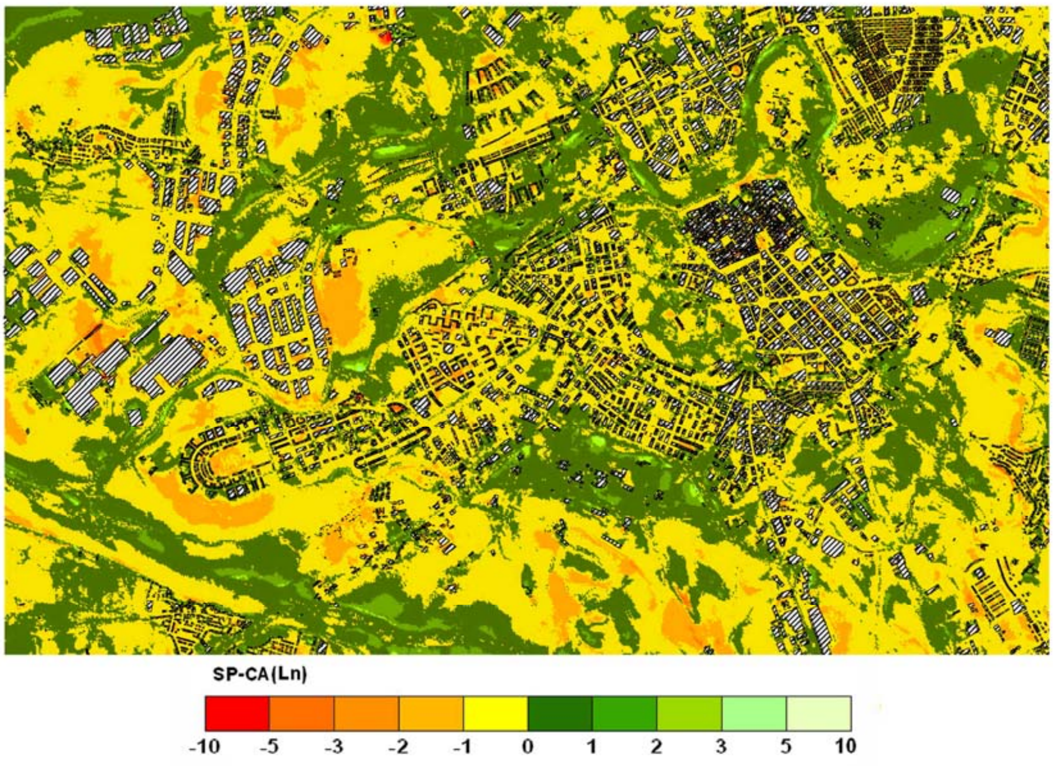

Figure 4 – Differences on Ln, in dB, from both programs (detail).

Figure 3 does not show an evident predominance of zones with a higher level neither from one nor from another program. In almost all areas differences-both positive and negative- are less than 1 dB. Looking at the figure 4 there is a certain similarity. Nevertheless, a subtle difference comes into sight. Now, in night period, greater negative differences appear, especially in open air zones distant from the emission lines. It must bear in mind that all the source variables -traffic flow, speeds, etc.- are identical for both software programs but the algorithms they make use of -discretization of the sources, reflection, etc.- are not exactly identical. Therefore, the ideal way to identify the cause of these differences is to display the Ld-Ln differences, that is to say, the difference among the differences from both programs (see Fig. 5). The implementation of the propagation under homogeneous and favorable atmospheric conditions varies according to the software programs resorted to.

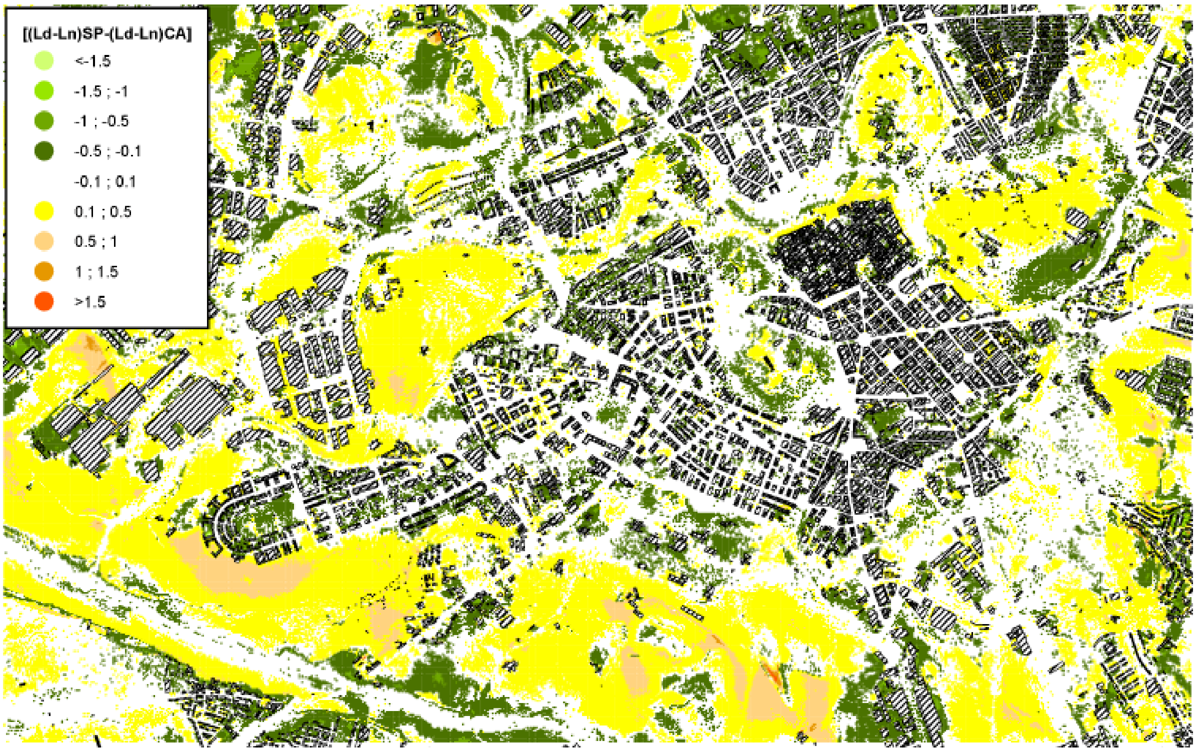

Fig. 5 – Differences between favorable and homogeneous atmospheric conditions from both programs, $[(Ld\text{-}Ln)_{SP}\text{-}(Ld\text{-}Ln)_{CA}]$, in dB.

A positive value in the map of Fig. 5 means that the difference between favorable and homogeneous conditions for propagation is lower in CA and a negative one means that it is higher in SP. Clearly, CA favors propagation under favorable atmospheric conditions. From a statistical point of view, there is yet another way to display the results with the aim of finding causes for the differences. By grouping the noise levels in ranges of 5 dB (from less than 50 dB to over 75 dB for Ld and from less than 45 dB to over 70 dB for Ln) figures 6 and 7 are obtained.

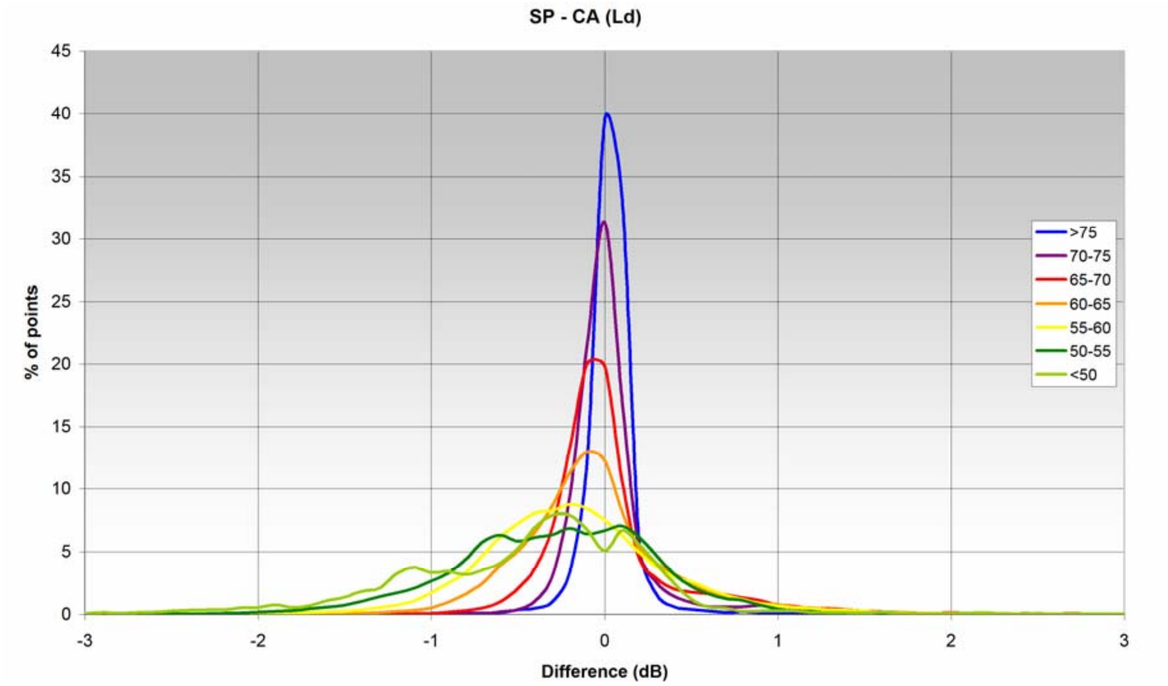

Fig. 6 – Normalised percentage histogram of differences by 5 dB ranges. Ld: day period

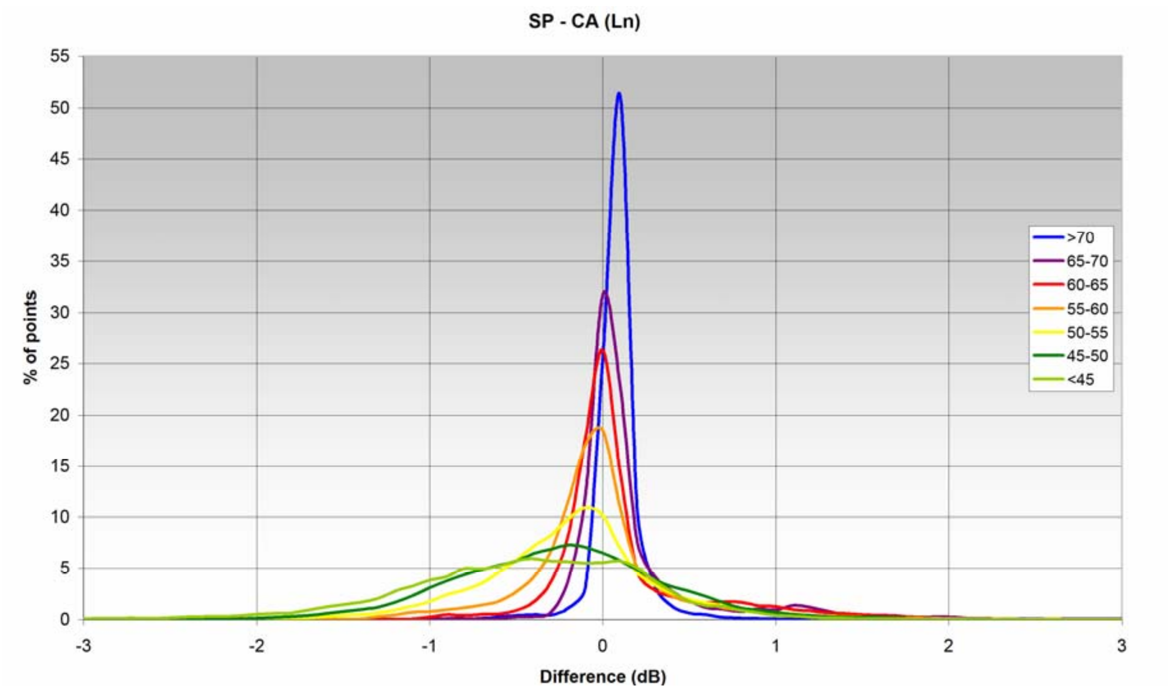

Fig. 7 – Normalised percentage histogram of differences by 5 dB ranges. Ln: night period

Three findings are achieved from these graphs. Firstly, the higher the noise level is (receiver points near the line sources) the lower the differences are. For Ld, only 2% of the receiver points with noise levels up to 70 dB differ over 1 dB. For Ln, such percentage is only 0.4%. Secondly, the lower the noise level is (receiver points either far away from the line sources or screened) the greater the differences are. For Ld, 20,7% of the receiver points with noise levels down to 50 dB differ over 1 dB. For Ln, such percentage is 13.6%. Finally, although the day and night period graphics are quite similar, a displacement of the lower ranges to positive differences is perceptible. These entire findings suggest that the accuracy of predictions is exceptional for receiver points with high levels when the source discretization algorithm is solely used- and assuming there is a reliable source model- but predictions deviate for receiver points with low levels when many algorithms have a bearing, namely order and depth reflection, diffraction, etc. Figure 8 (Ld) and figure 9 (Ln) show identical results although through accumulated distribution.

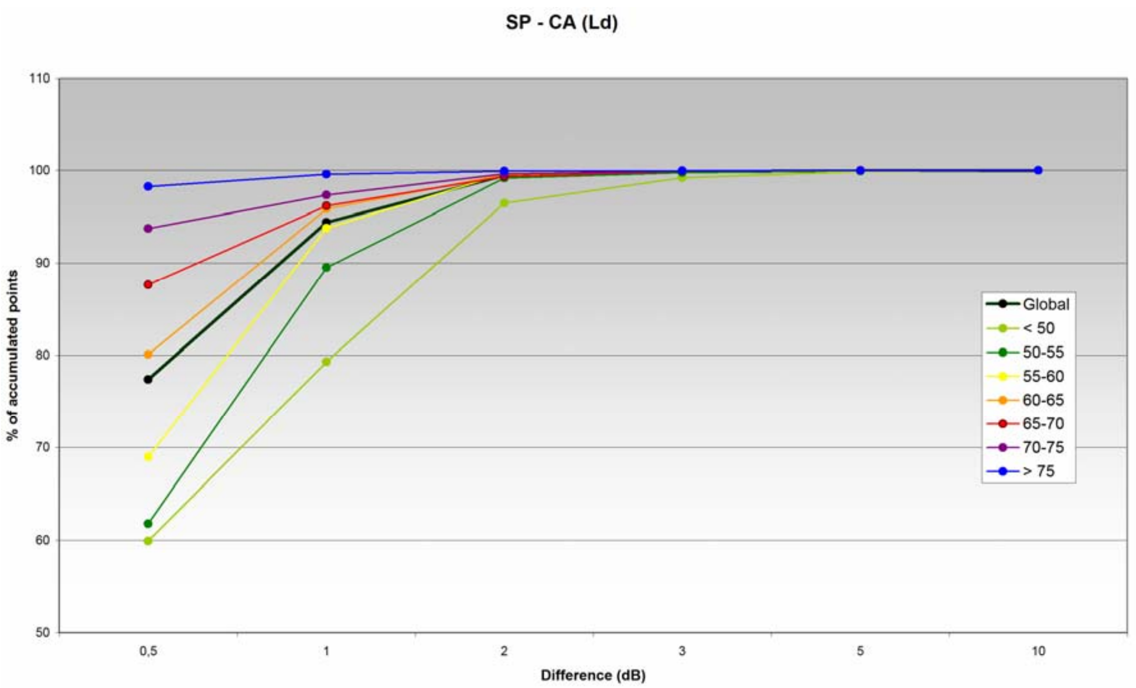

Fig. 8 – Accumulated percentage histogram of differences - Ld: day period

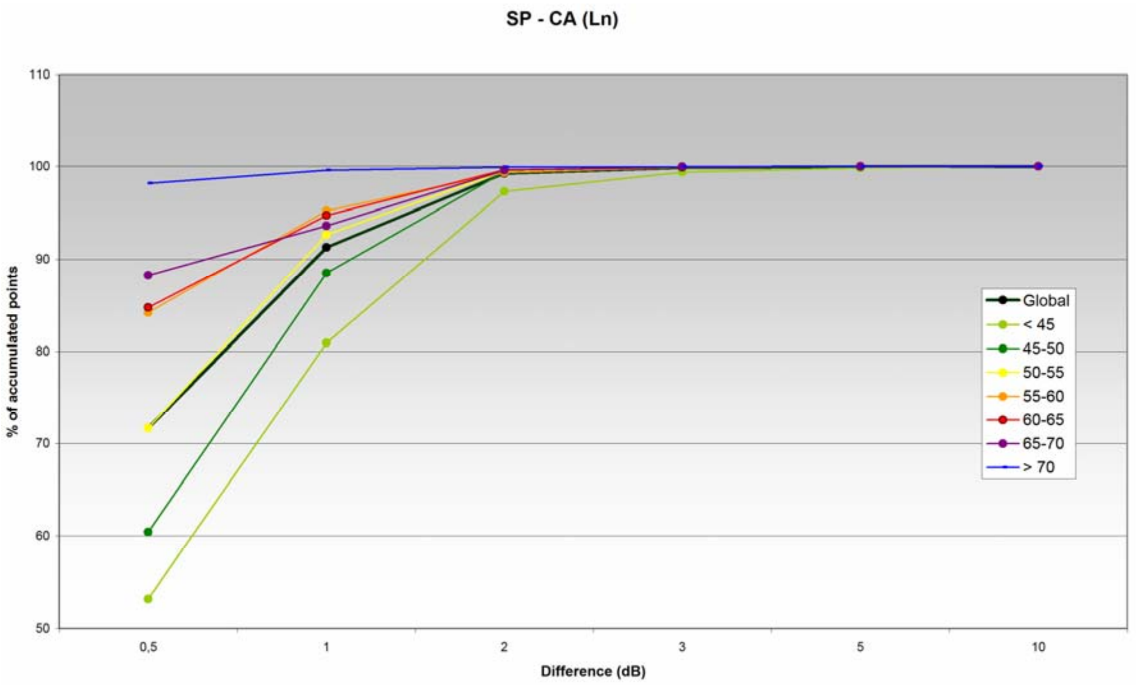

Fig. 9 – Accumulated percentage histogram of differences - Ln: night period

4 Conclusions

Two of the most widely used programs for the prediction of environmental noise have been used to determine the noise map of the agglomeration of Pamplona. All the initial data, both to generate the DGM (elevation points) and to define the sources of noise (roads, traffic flow, speeds, etc.) were exactly the same. The French method, NMPB, was used to evaluate noise levels on the grid-with a total of $1,27x10^6$ points, approximately. Configuration of the calculation parameters was the most equivalent model that programs allowed. In spite of that, many differences appeared in the findings. Differences were due to the various algorithms that programs implement to evaluate noise levels.

Although in 94.4% (Ld) and in 91,3% (Ln) of the points the difference in the noise level calculated from the two programs was less than 1 dB, this general statistic result concealed some great differences. Most differences were related to points which were highly screened or located far away from the sources. In the former, the algorithm of visibility was the main cause of such differences. In the latter, differences were mainly brought about by a different implementation of the propagation under homogeneous and favorable atmospheric conditions from both software procedures.

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