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Using Noise Mapping to Evaluate the Percentage of People Affected by Noise

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Summary
In noise mapping, the European Directive 2002/49/EC requires an estimation, to the nearest hundred, of the number of people living in dwellings that are exposed to different bands of Lden values in dB 4 m above the ground on the most exposed façade. Even though this methodology always overestimates the effects caused by noise, this estimation is accurate enough for detached or semidetached houses in urban areas. However, for large and tall buildings in urban configuration, this estimation could be confusing and even very vague. In fact, differences regarding the percentage of people affected by noise taken from an exact calculation and from European Directive criterion could be unacceptable. When façade noise map calculation is not possible, either due to being too time consuming or unavailability of software resources, estimating people affected by noise based on the nearest grid point approximation criterion is clearly preferable to the European Directive approach.

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1. Introduction

One of the most negative effects of environmental noise in urban zones is probably sleep interference. Exposure to noise can induce sleep disturbance seen in difficulty falling asleep, alterations in sleep patterns or depths and awakenings. These effects are referred to as primary sleep disturbance effects. Other primary physiological effects that can be induced by noise during sleep are increased blood pressure, increased heart rate, change in respiration, body movements, etc. Exposure to night-time noise can also induce secondary effects (that is, effects that can be measured the day after the noise exposure) including lower perceived sleep quality, increased fatigue and poorer performance [1]. Noise pollution levels are strongly correlated with the percentage of people highly annoyed by noise by means of noise indices in general use. The well known graph prepared some years ago by Schultz, summarizing the information found from different social surveys [2], makes this correlation clear for the Ldn indicator. An extensive noise survey carried out ten years ago found concordant results [3].

The European Directive 2002/49/EC (*Environmental Noise Directive* [4], henceforth END) requires, in Annex VI (data to be sent to the commission for agglomerations), an estimation of the number of people (in hundreds) living in dwellings that are exposed to each of the following bands of Lden values in dB 4 m above the ground on the most exposed façade: 55–59, 60–64, 65–69, 70–74, > 75, separately for noise from road, rail and air traffic, and from industrial sources. The figures must be rounded off to the nearest hundred (e.g. 5200 = between 5150 and 5249; 0 = less than 50). A similar requirement is stated for the Lnight index for the following bands of values: 50–54, 55–59, 60–64, 6-5-69, > 70. An additional 45–49 band may be required. Even though this methodology always overestimates the effects of noise, this estimation is accurate enough for detached or semidetached houses in urban area. However, for large and tall buildings in urban configuration, this estimation could be confusing and even very vague. The procedure recommended by the European Commission Working Group-Assessment of Exposure to Noise [5] follows the "precautionary principle". Nevertheless, both computational methods and cadastral information are rapidly improving and new analysis and subsequent methodologies focused on more accurate estimations must be proposed.

The percentage of people affected by noise (more exactly, the percentage of people whose façade noise level exceeds a certain figure) may be evaluated from results of a noise map. This evaluation can be carried out in an exact way by means of a detailed façade noise map and assuming that the number of people living in each flat is known. For a medium-sized or big city the greatest difficulty is how much time is consumed by calculating the façade noise map. Nevertheless, the strict END requirement can be met by calculating noise levels at façade receiver points placed horizontally every 3 metres -for instance- and 4 m above the ground. This calculation could also be approximated using figures obtained from a horizontal noise map, 4 m above the ground, because (for the purposes of informing citizens in accordance with Article 9 and the develop-

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Figure 1. City of Pamplona and location of the district case study.

ment of action plans in accordance with Article 8 of the END) additional and more detailed information, such as a graphical presentation, must be given. Common noise maps have been produced using a 10×10 m or 5×5 m grid. Points on these grids can be placed at a distance from 0 to 7 m or from 0 to 3.5 m to the façades, respectively. Assuming that noise sources are not very close to façades, the noise level evaluated at these points of the grid reliably represents the noise level at the façade.

However, the two aforementioned approximations might vary in accuracy depending on the urban configuration, due to different heights of buildings and the distance between them. For detached or semidetached houses, exact calculations on façades will give similar figures to those obtained at the nearest grid point. With regard to the calculation parameters, it should be kept in mind that only incident sound is considered, which means that no account is taken of the sound that is reflected from the façade of the dwelling under consideration (as a general rule, this implies a 3 dB correction in case of measurement).

Obviously, reflections coming from others facades are taken into account. Nevertheless, reflections from facades are not neglected in grid point calculations. In some noise prediction software the 'minimum reflector-receiver distance' parameter can be used to prevent the reflection on the facade contributing to noise level calculation. For instance, by using the figure of 1 m for the aforementioned parameter it makes quite sure that the reflection in question is neglected. Nevertheless, this implies that the reflection is not taken into account for grid points either as it is less than 1 m from the façade in question. For grid points more than 1 m from the façade, reflection is considered.

2. Case study

In this work, the number of people affected by noise in a district of the city of Pamplona (Spain) has been evaluated using three different methods.

1. Façades noise map. This represents the actual noise level on each flat's façade. Receivers were distributed according to the German method VBEB [6]. This will henceforth be referred to as *exact* estimation.
2. Strategic noise map. This implies assigning the noise level on the nearest grid point obtained through the strategic noise map, 4 m above ground, as the noise level for a specific façade. This procedure has been made by using a GIS package. This will henceforth be referred to as *approximated* estimation.
3. Environmental Noise Directive estimation. This implies assigning the noise level existing, 4 m above ground, on the most exposed façade of the building as the noise level for a specific façade-flat. This will henceforth be referred to as *END* estimation.

Seeing that both methods 1 and 3 do not take reflected sound into account, a figure of 0.01 m was selected for the minimum reflector-receiver parameter distance. Otherwise, method 2 would overestimate the noise effects.

The location of the case study is part of one of the districts of Pamplona; Iturrama district. The calculation area, 149.600 m^2, is approximately a quarter of the district. It is shown in Figure 1. The Digital Terrain Model (DTM) is very simple since this part of the city is very flat. There are 30 buildings inside the calculation area but each of them is formed by blocks. The total number of blocks is 105. It was necessary to divide up the area into blocks because the available information about the number of residents was provided in this way. All the flats within the same block have the same street door. Building heights vary from 22 to 55 m; or in other words from 6 to 17 floors. The number of people living in the calculation area is 5695. The CadnaA. v.3.6 [7] package was used. According to END recommendations (for Member States that have no national computation methods or Member States that wish to change computation method) the French national computation method 'NMPB-Routes-96' [8] was used for calculations.

All the data influencing both noise emission (roads, traffic density, composition, speed, etc.) and propagation (green areas, absorption coefficients, etc.) were extracted from the Noise Map of the Agglomeration of Pamplona, carried out over the past year [9]. Thanks to both the Mu-

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nicipal Government and the Government of Navarre's participation in this work, the data are very accurate: annual average traffic density, people living in each flat, etc. The number of receiver points, on the grid noise map, was 1149. This number is the result of excluding points inside the buildings which take up 34700 m^2 from the total amount of 1496 grid points. To calculate the façades noise map, the number of receiver points was 9115. The calculation time for façades was, approximately, seven times higher than that needed for the grid noise map. This ratio represents an important limitation when evaluating a façades noise map for a medium-sized or large city with this type of urban configuration.

3. Results

Figure 2 shows the number of people affected by noise, as a histogram as well as an accumulated percentage, for the Lden noise index. Under the assumption that *exact* calculation (noise on their own façade) represents the actual effect, great differences appear with regard to *approximated* calculation (noise on the nearest grid point) and particularly compared to the END estimation (noise on the most exposed façade of the building). Thus, although the 22% of people are actually exposed to noise, Lden, over 65 dB, this percentage rises to over 94% under the END approach. From the nearest grid point criterion, *approximated* estimation, the value is close to 50%. Figure 3 shows the results for the Ln noise indicator. Similar percentages to those mentioned above are obtained for the figure of 55 dB.

Undoubtedly, the criterion used by the END is very vague and does not represent people's actual exposure to noise, at least for the analyzed urban configuration. When façade noise map calculation is not available, either because it is too time consuming or due to unavailability of software resources, estimation of people affected by noise using nearest grid point approximation is clearly preferable to the END approach.

As stated in Annex 3 (*assessment methods for harmful effects*) dose-effect relations should be used to assess the effect of noise on population. In particular, relation between annoyance and Lden as well as relation between sleep disturbance and Ln for the different sources of noise. If necessary, dose-effect relations could be presented for dwellings with a quiet façade. A quiet façade means the façade of a dwelling where the Lden value four metres above the ground and two metres in front of the façade, for noise emitted from a specific source, is more than 20 dB lower than on the façade with the highest Lden value. According to Annex 6 (data to be sent to the Commission) it should be stated, where appropriate and where such information is available, how many persons, in categories, live in dwellings that have a quiet façade.

In order to calculate the number of buildings (in our case study) with a quiet façade the difference has been evaluated between the maximum and minimum level, four meters above the ground, for each building. Buildings are

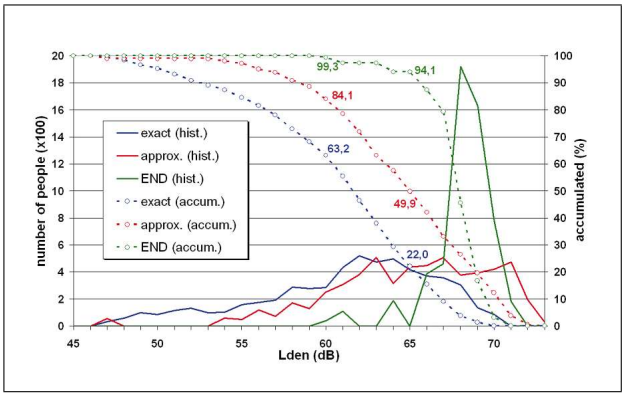


Figure 2. Number of people, in hundreds, affected by noise (histogram and accumulated) evaluated by three different estimations. Noise index: Lden.

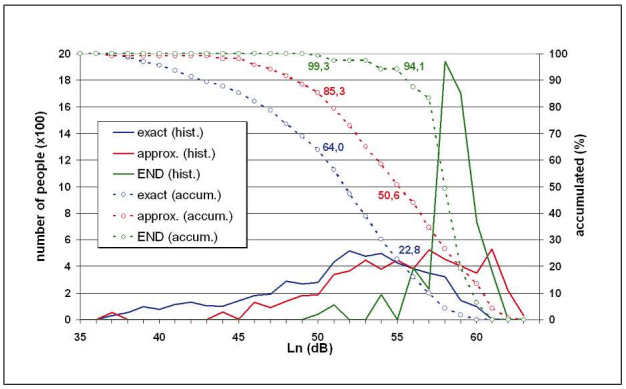


Figure 3. Number of people, in hundreds, affected by noise (histogram and accumulated) evaluated by three different estimations. Noise index: Ln.

made up of blocks, so the maximum and minimum levels of each building are assigned to all blocks that make up the building. The result is that only one building (shown in red in Figure 1) has a quiet façade.

4. Discussion

4.1. Analysis of the differences

When evaluating the percentage of people affected by noise from the *approximated* criterion (assigning the noise level at the nearest grid point to the façade receiver considered) there are not generally any outstanding differences with regard to the exact calculation at the same height. Obviously, any differences are generally due to differences in height but they could be due either to screening the grid receiver or the façade receiver. In some cases, differences can be considerable. Figure 4 suggests some explanations.

Blue points E1, E2 and E3 show receivers located on the façades, green points G1 and G2 show grid points and red point E4 is a receiver located at the façade of the highest block. Façade points are situated at different heights in order to also evaluate these differences. E1 is 4 metres above the ground, E2 and E3 are at 22 metres and E4 is 25 metres high. Obviously, green points have the same height

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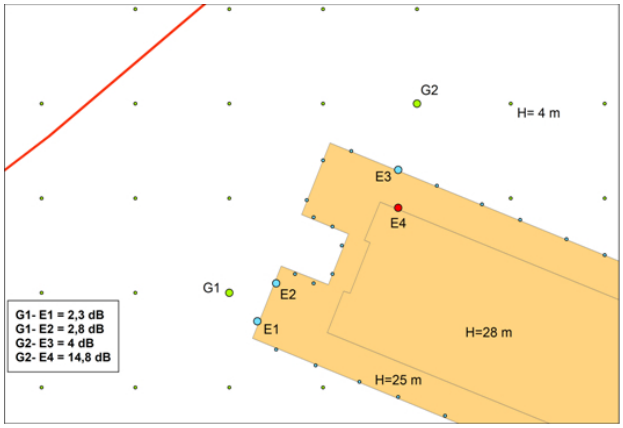


Figure 4. Analysis of the differences.

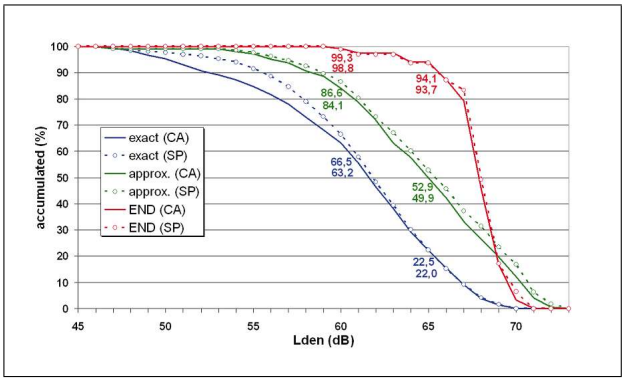


Figure 5. Differences in the number of people affected by noise-accumulated, evaluated in two packages by three different estimations. Noise index: Lden.

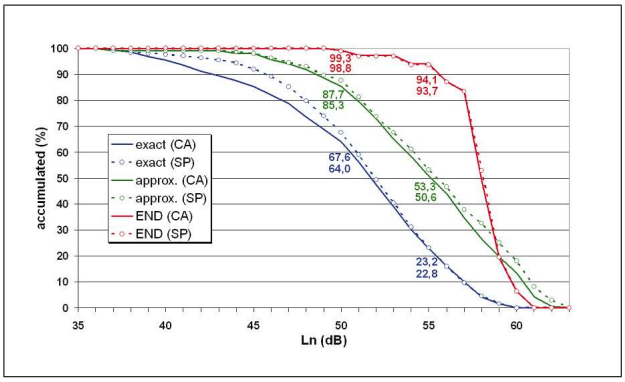


Figure 6. Differences in the number of people affected by noise-accumulated, evaluated in two packages by three different estimations. Noise index: Ln.

than the grid, 4 metres. In this diagram it is possible to find two different situations. In the first one, the G1 level is assigned to E1 and E2 and the differences are not so remarkable. In both cases the distance to the road and the reflections (which are only taken into account in grid points) can explain the differences which are generated. The different height of the receivers (G1-E2) does not imply a big increase of error in that case. However, in the second case, where noise levels at points E3 and E4 are given by the level of G2, the increase in height and the different location of the points generate a 10 dB difference. To explain that difference it is necessary to introduce the concept of 'visibility'. The diagram shows that E3 has a direct contribution from the road; however E4 does not have a direct view of the source. This point, located on the 28 metre building, has been screened by the smaller one and this is the reason why great differences are generated between the two façade points. In this second case, the error generated by assigning grid point levels to the façades is due to three parameters: distance to the source, reflections and visibility. For example, point E3 has a small amount of screening from the corner of its own building and contribution of the reflections is not taken into account in this point, so the level in the receiver E3 is 4 dB less than grid point G2.

4.2. Results from two software packages

All the results explained above were obtained from the Cadna (CA) package, V.3.6. Identical calculation was carried out from other commercial package, Sound PLAN (SP) V. 6.5 [10]. It is not possible to configure the calculation parameters from either package in the same way. Nevertheless, calculation parameters were chosen to be as similar as possible as shown in Table I.

Figures 5 and 6 show the results obtained from the two packages for accumulated distribution of people affected by noise through *exact, approximated* and *END* criterion for Lden and Ln indices.

As can be seen, differences are very small, especially using either the END criterion or the approximated criterion. For the exact criterion one of the programs (SoundPLAN) predicts a higher percentage of people affected by noise that the other one (Cadna). Because differences are larger for low noise level ranges, receiver points far from sources, it is to be expected that different algorithms are implemented in the two programs with regard to the propagation model.

5. Conclusions

The criterion stated in the END to evaluate the percentage of people affected by noise is very vague and does not represent people's actual exposure to noise. For urban configurations such as the area analysed here, this percentage might be drastically wrong and it is significantly overestimated. When façade noise map calculation is not available, either due to being too time- consuming or due to unavailability of the software resources, estimation of the people affected by noise under nearest grid point approximation is clearly preferable to the END approach.

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Table I. Configuration of the parameters for both programs.

Parameter	Cadna	SoundPLAN
Discretization of the sources	Raster factor = 0.5	Angular step: 1°
Maximum search radius	1000 m	1000 m
Lateral diffraction allowed	No	No
Tolerance (maximum error)	0	0
Grid interpolation	No	No
Calculate points inside buildings	No	No
Building absorption	0.21 (=1dB)	1dB (=0.21)
Ground absorption	0.1	0.1
Correction limit by diffraction	25 dB	25 dB
Reflection order	1	1
Reflection depth	Infinite	1
Max. search radius of reflecting surfaces	100 m	Not
Max. search radius of reflecting surfaces	100 m	Not
Min. distance receiver-reflector and	1 m	Not available
interpolation (for reflection)	Interpolate to 1 m	Not available
Max. distance source-receiver and	1000 m	Not available
interpolation(for reflection)	Interpolate from 1000 m	Not available

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