Construction of an average indicator of potential noise exposure, and its sensitivity analysis in Marseilles city (France)

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The present study was undertaken by SolData Acoustic and the Health regional Observatory (Southeastern France) within a research project aiming at the study of the links between road noise exposure and psychotropic drug consumption on a small-area level in the city of Marseilles. At first, we built an average indicator of potential road noise exposure (PNEI) for the population living in each census block (the smallest sub municipal division with 1500 inhabitants on average). We calculated noise exposure using CadnaA software according to the END for noise mapping, and applied some improvements: we used observed mean speeds (instead of speed limitations), calculated mean noise level for each building (instead of maximum levels), and took floor levels into account. Secondly, we performed a sensitivity analysis in order to assess the impact of the variations of several parameters on model outputs. Sensitivity analysis shows that the most influent input parameters, at a global scale, are road surface type, speed and traffic. Propagation of uncertainties was performed on those parameters. And at last, uncertainties calculations on the PNEI indicator will be taken into account in the analysis of the links between road noise exposure and psychotropic drug consumption.

1 Context and objectives

The present study was undertaken within a research project aiming at the study of the links between road noise exposure and psychotropic drug consumption in the city of Marseilles (852,395 inhabitants in 2007; 240.62 km^2).

The spatial scale was defined at the French census block level, a sub municipal division designed by the National Institute for Statistics and Economic Studies (INSEE).

The purposes of this study are:

- To build an average indicator of potential road noise exposure (PNEI) for the population living in each census block.

- To perform a sensitivity analysis in order to assess the impact of several input parameters on noise model outputs.

- To build a methodology for the calculation of uncertainties on PNEI indicator.

2 Construction of a potential road noise exposure indicator (PNEI)

2.1 Methodology

Annual road traffic noise levels were modeled across Marseilles in 2006 in accordance with the requirements of the Environmental Noise Directive (END) 2002/49/CE. We used the environmental noise prediction model CadnaA (Datakustik) for the calculation of acoustic propagation in 3D and noise mapping according to NMPB 1996.

Noise calculations were implemented using annual average daily traffic data including information on traffic intensity (average number of vehicles per day travelling on each road segment), traffic composition (percentage of light and heavy vehicles), traffic type (congested or not), and also traffic speed limits. Traffic information was available from the various transport authorities in Marseilles city (for the year 2006).

We estimated the number of inhabitants in each building by distributing the population of each census block (INSEE, 2006) between its apartment buildings proportionally to their volume.

In order to get closer to more realistic situations we decided to apply further improvements on noise calculations:

- <u>Use of observed mean speeds as input data</u>, instead of speed limitations. No data were available for the city of Marseilles, but we used the results of speed measurements campaigns realized in France between 2004-2008 for the National Interministerial Observatory for Road Safety (ONISR) [1] :

Table 1: Mean speed used in noise model, from ONISR (2007 data)

Road type / Speed limit (km/h)	Mean speed used (km/h)	
	Light vehicles	Heavy vehicles
50	46	50
70	70 (*)	70 (*)
90	82	78
110	109	91
130	120	94

(*): no data available

- <u>Considering the energetic mean instead of the maximum level for the assessment of the average noise exposure of people living in building $Lden_{bât}$</u>. In fact noise mapping according to the END is using maximum levels for each building, and this method overestimates noise exposure.

Another PNEI calculation using arithmetic means instead of energetic means will also be performed.

- <u>Taking into account floor levels</u>

Noise mapping according to the END is calculated at 4m above ground and for high buildings, noise exposition is overestimated.

In base of a CSTB study [2] and specific noise simulations with CadnaA, we considered an attenuation of 5 dB(A) above 10th floor (33m) in case of high density census block, or above 5th floor (18m) in case of low density census block.

The results of noise mapping are then computed in order to calculate an average potential noise exposure indicator (PNEI) for road traffic using the following formula:

$$PNEI_{Lden} = 10.\log\left(\frac{1}{nhab_{tot}} \sum_{bât=1}^{N} nhab_{bât}.10^{\left(\frac{Lden_{bât}}{10}\right)}\right) \quad (1)$$

Where:

$PNEI_{Lden}$: average potential noise exposure indicator for a census block, for Lden indicator

Lden : noise indicator Lden calculated on façade

$Lden_{bât}$: average L_{den} on the façades of a building (energetic mean)

N: number of buildings in the census block

$nhab_{bât}$: number of inhabitants in each building

$nhab_{tot}$: total inhabitants for a census block

2.2 Results

Potential noise exposure indicators are calculated for Lden and presented below.

High values of PNEI are met near historical center and along the motorways at north and east. Low values of PNEI are met at the periphery of the city.

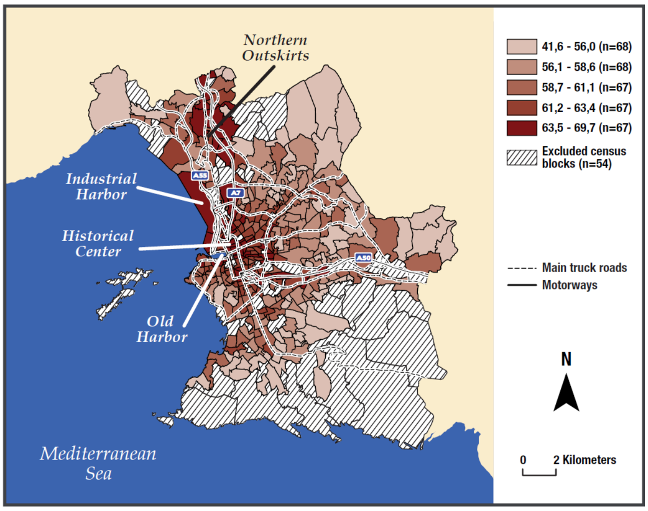

Figure 1: Potential noise exposure indicator for Lden ($PNEI_{Lden}$) at each census block of the city of Marseilles (n=338).

3 Sensitivity analysis

The objective of sensitivity analysis is to identify the most influent parameters in terms of PNEI calculation, and to get all important data for the uncertainty analysis.

3.1 Identification of the most influent parameters

Using CERTU guidelines [3] we choose a first list of influent parameters, and we defined some preliminary tests with arbitrary variations of those parameters.

Table 2: Preliminary tests for the identification of the most influent parameters

Parameters	Parameter variations	Influence
Noise Emission (road)		
Traffic	From - 50 % to + 50%	+++
% heavy vehicles	From 0% to 100%	++
Speed	From - 20km/h to + 20 km/h	+++
Road surface type	From « Enrobé bituminé » everywhere to « Enrobé acoustique » everywhere	-
Traffic type	From « fluid » everywhere to « congested » everywhere	+
Noise Propagation		
Height of screens	From « all screens height = 0m » to « all screens heights = 6 m »	-
Topography	Deactivation of the topography	-
Calculation		
Number of reflections	From 0 to 2	++
Ray path length	From 500m to 2000m	-
Grid spacing	From 5m x 5m to 20m x 20m	++
Calculation height	H =2 , H=4 et H=6m	++

The most influent parameters seem to be traffic, speed, heavy vehicles percentage, grid spacing and calculation height. The number of reflection is also important but it will always be set to 2.

3.2 Determination of variation intervals or distribution of the most influent parameters

In order to perform sensitivity analysis and uncertainty calculation, we need information about variation intervals or statistic distribution of the most important parameters.

Those information were found using [1] for speed data and NANR 93 research project [4] or WG-AEN tool-kits [5] for other data.

3.3 Monoparametric sensitivity analysis

Method:

The sensitivity analysis was carried out using a specific feature of CadnaA software which is able to calculate the standard deviation in dB(A) at each receiver point of a grid, when the standard deviation of the sound power level of the sources are known.

This feature developed by Datakustik [6] is based on the GUM [7] principles and is valid under assumptions of normal distributions and uncorrelated noise sources.

CadnaA calculates two grid maps:

- A reference grid map with noise levels like $Lden_{i,j}$
- Another grid map with the corresponding standard deviations $\sigma Lden_{i,j}$

Where i and j are grid map indices.

The range of variation of PNEI is then calculated using a simplified method: lower value of PNEI are obtained using formula (1) on noise map ($Lden_{i,j} - 2.\sigma Lden_{i,j}$) and higher value of PNEI are obtained using formula (1) on noise map ($Lden_{i,j} + 2.\sigma Lden_{i,j}$).

Results:

A potential noise exposure indicator is calculated on the whole territory: PNEI_Lden = 60,6 dB(A), and the ranges of variation of PNEI are presented below.

Table 3: Results of monoparametric sensitivity analysis

Parameter	Range of variation of $PNEI_{Lden}$ in dB(A)
Road surface type	1,99
Speed	1,86
Traffic	0,78
% of heavy vehicles	0,66
Speed fluctuations	0,66

The most influent parameters in the context of our study are road surface type, speed and traffic parameters.

4 Uncertainty analysis

The aim of uncertainty analysis is to calculate the uncertainty of the potential noise exposure indicator PNEI. This uncertainty will then be used in the study of the links between road noise exposure and psychotropic drug consumption.

Uncertainties taken into consideration are those depending on input parameters (identified through sensitivity analysis). We also took into account the spatial variability of potential noise exposure inside census blocks.

4.1 Uncertainties on most influent parameters

The global uncertainty related to the most influent parameters (speed, traffic, and road surface, see results of sensitivity analysis) is calculated using propagation of uncertainties techniques.

First we calculate the global uncertainty of each road segment in CadnaA, as the quadratic sum of the uncertainty related to each parameter.

Secondly we calculate noise maps with the same method as described in (§ 3.3).

Then some Monte Carlo simulations are performed in order to calculate uncertainties on $PNEI_{Lden}$ and $PNEI_{Ln}$

4.2 Spatial variability inside census blocks

In our study, all residents of a census block are considered with the same potential noise exposure indicator ($PNEI\_Lden_k$).

The purpose is here to calculate the spatial variability of potential noise exposure to road traffic, inside a census block.

We analyze the statistical distribution of the absolute deviations between each building exposition and the average PNEI of the census block.

In order to compare the uncertainties between census blocks, spatial variability of a census block is divided by the average PNEI. $U_k'(\%)=(U_k*100)/PNEI\_Lden_k$.

The results show higher spatial variability for census blocks with large dimensions and large number of buildings.

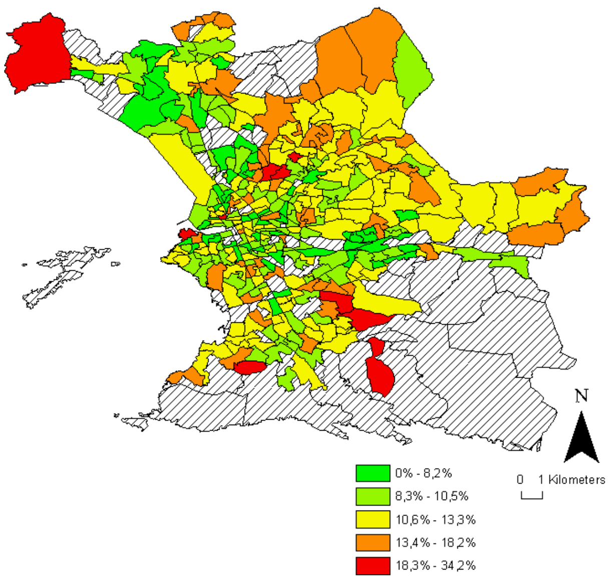

Figure 2: Spatial variability of potential noise exposure on road traffic Lden (%)

This analysis shows important values of spatial variability of potential noise exposure: for most of the census blocks, those values are greater than uncertainties related to input parameters.

4.3 Discussion and perspectives

In this paper we showed how noise mapping calculation can be improved to get closer to more realistic situations than standard END method.

We built an average indicator of potential road noise exposure (PNEI) which will be used within the study of the links between road noise exposure and psychotropic drug consumption in the city of Marseilles.

We also proposed an original method for the assessment of PNEI uncertainties.

Some difficulties where found in collecting data corresponding to variation intervals or statistic distribution of the main important parameters for noise mapping.

Uncertainty analysis are made over a large set of input datasets, and we made assumptions about the global independence of noise sources and input parameters at the scale of a census block, when the reality is more complex because some input datasets cannot be considered completely uncorrelated. According to discussion with other researchers, we feel it is an area which needs greater investigation in order to draw robust conclusions.

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