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FA2020/450 STRATEGIC NOISE MAPS OF THE LYON AND GRENOBLE AGGLOMERATIONS: CASE STUDY FOLLOWING THE NEW CNOSSOS-EU CALCULATION METHOD AND THE INCLUSION OF THE HEALTH IMPACT OF NOISE

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ABSTRACT

Directive 2002/49/EC on the assessment and management of environmental noise requires Member States to establish Strategic Noise Maps (SNM) for transport (road, rail and air) and industrial noise. Since January 1 2019, SNMs must use a unified calculation method: CNOSSOS-EU. This method was used for the computation of SNMs of road noise in the Grenoble agglomeration produced in 2019. This case study presents an assessment of the impact of the changeover by comparing the results obtained with the new method and those obtained with the old method (NMPB08) for the same territory, as well as the methodology used to make the input data used for both methods compatible and comparable (traffic type, vehicles, surface). The results of the SNMs for the agglomerations of Lyon and Grenoble (Round 3) were also used for the assessment of the health impact of noise. This impact is presented in accordance with World Health Organization (WHO) recommendations, in terms of Disability-Adjusted Life Year (DALY), in anticipation of future requirements in Annex III of the Directive.

1. INTRODUCTION

European Directive 2002/49/EC [1] of 25 June 2002 require Member States to establish Strategic Noise Maps (SNM) in order to assess exposure to environmental noise. These maps are made available to the public and enable the implementation of Noise Action Plans (NAP) to reduce noise and to estimate the impact of new infrastructures on the noise environment. Transport and industry noise emissions are considered. SNM implementation is compulsory for urban areas with more than 100 000 inhabitants and for major roads, railways and airports. The Directive specifies common noise indicators to determine noise exposure. Pending the adoption of a common assessment method, Member States have been allowed to use their national methods. For example, in France, the forecasting method NMPB08 has been used [2]. The common method, called CNOSSOS-EU for "Common Noise Assessment Methods in Europe" [3] was published in the Official Journal of the European Union on 19 May 2015 in order to harmonize the production of SNMs between all European Union countries. The first SNMs based on this method were expected in 2019.

The SNMs for the road source, from Grenoble-Alpes Métropole, were calculated with this method. The results

showed lower noise levels and fewer inhabitants exposed to high levels, compared to the maps of the previous round. It was therefore necessary to assess which part of the noise levels reduction was due to the actions implemented by the Grenoble-Alpes Métropole, to feed the local NAP, and which was linked to the change in method. The methodology used and the results are presented here. Furthermore, in anticipation of the future requirements of Annex III, the health impact of transport noise was assessed for the agglomerations of Lyon and Grenoble. The methodology and results are presented here.

2. STRATEGIC NOISE MAP OF GRENOBLE-ALPES METROPOLE (ROAD NOISE)

As far as the calculation of environmental noise propagation is concerned, the changes made by the new CNOSSOS method compared to the French method are not considered fundamental. This is not the case for the computation of noise emission terms. When the Grenoble agglomeration SNMs were produced, the CNOSSOS method as implemented in the modelling software, was used to fill in the input data as expected (vehicle categories: 1, 2, 3, 4a, 4b). With regard to the exposure of the population, the method consisting of retaining the level at 2 meters from the most exposed façade was used. Indeed, the method for assigning noise and population levels to buildings, as defined in Annex II (paragraph 2.8) of the Directive [1], was not operational in the software (and is not yet fully operational, it is a work we are carrying out in relation with the manufacturers in order to be ready for the agglomeration NSMs of the next round). This corresponds to the cases of buildings whose floor dimensions indicate the existence of only one dwelling per floor (Annex II, paragraph 2.8 CASE 1 (e)).

2.1 Input Data

The data for topography, absorption, buildings with affected population and screens are strictly the same regardless of the method. Concerning the source, the road line used is the same, the pavement surface (BBSG 0/10 which corresponds to a non-porous surface of category

R2¹⁾ and the overall traffic are also identical for both methods. What changes is the nature of the traffic and its distribution:

- Two categories for calculation with NMPB08: light vehicles and heavy vehicles.
- Five categories for calculation with CNOSSOS:

Category	Name	Distribution for Grenoble [4]
1	Light motor vehicles	
2	Medium heavy vehicles	40% of total categories 2 + 3
3	Heavy vehicles	60% of total categories 2 + 3
4a	Powered two-wheelers (<50 cm ³)	53% of total categories 4a + 4b
4b	Powered two-wheelers (>50 cm ³)	47% of total categories 4a + 4b

Table 1. Vehicles categories with CNOSSOS

Thus, for the same section, the fact of distributing the traffic into different vehicle categories means that the sound power levels at emission are lower with the CNOSSOS method (Figures 1 and 2).

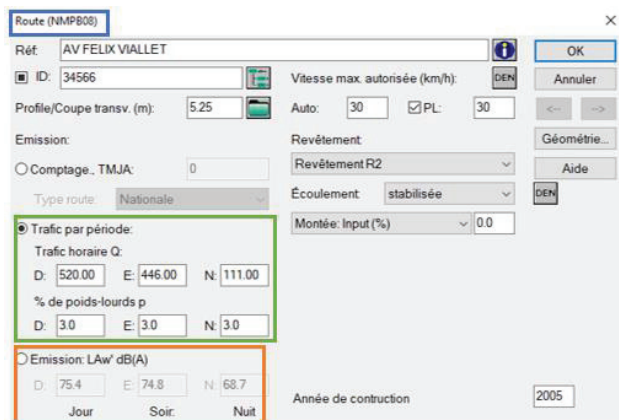


Figure 1. Editing vehicle categories NMPB08 – CadnaA© software DataKustik – 2019

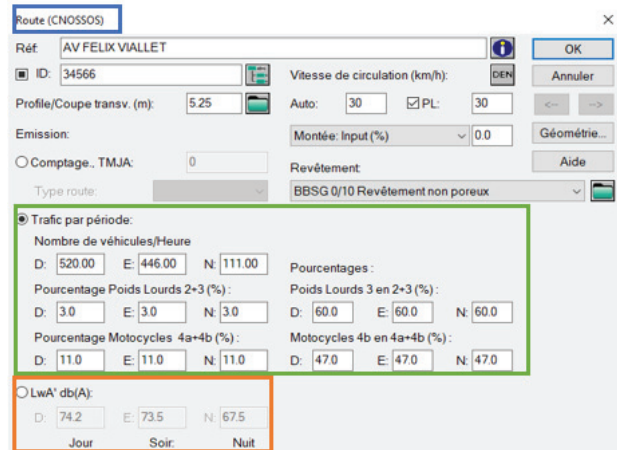


Figure 2. Editing vehicle categories CNOSSOS – CadnaA© software DataKustik – 2019

2.2 Calculation configuration

The configuration of the calculation is similar. The following parameters have been entered identically for each method:

- A search radius of 2,000 meters.
- An angular scanning method (100 sound rays).
- A maximum order of reflection of 2.
- A meteorology with favourable local occurrence values.

2.3 Results of the calculation of SNMs for the road source of the Grenoble-Alpes Metropole (CNOSSOS)

Only road SNMs were calculated using the CNOSSOS method (type A and C maps, for Lden² and Ln³ and population exposure table). The type A (levels) and type C (exceedance of the limit value of 68 dB(A)⁴) maps are available on the Grenoble-Alpes Metropole website⁵.

The results show lower levels of exposure than those obtained at the previous round (5 years ago). It was therefore necessary to evaluate the part linked to the change in standards (change from the national method NMPB08 to the common European method CNOSSOS) and the part linked to the implementation of actions, by the Grenoble-Alpes Metropole, in favour of improving the noise environment (in particular the speed limit of 30 km/h, in city centres). This exercise was essential to feed the NAP (Round 3).

For this reason, the calculation has also been performed with the NMPB08 method as implemented in the CadnaA© software, keeping the same input data (except

¹ in accordance with the [decree of June, 1st 2018 relating to the establishment of noise maps and environmental noise prevention plans](#)

² The Lden indicator (Level day evening night) is a 24-hour indicator that takes into account the increased sensitivity of individuals to noise in the evening (+5 dB(A) weighting) and at night (+10 dB(A) weighting).

³ The indicator Ln is the noise level over the night period (22h-6h).

⁴ Limit value determined by the Member State. In France, the limit value for road noise is 68 dB(A) (*Article 3 of the Decree of 24 March 2006 on the establishment of noise maps and environmental noise prevention plans and amending the town planning code*).

⁵ <https://www.lametro.fr/469-lutte-contre-le-bruit.htm>

the division into different vehicle categories) and the same calculation configuration parameters.

2.4 Comparing the results between the two methods (CNOSSOS and NMPB08)

Noise Map (road source) calculated with **NMPB2008**
 Exposure population table
 Grenoble-Alpes Metropole - Revision 2019 acoucité

Lden road	Exposed population (inhabitants)	Exposed population (%)
Lden in dB(A)		
< 55	34 316	7.7
[55-60[	110 404	24.8
[60-65[	214 922	48.2
[65-70[	72 370	16.2
[70-75[	13 166	3.0
>=75	337	0.1
Total	445 516	100.0
Exceeding limit >=68 dB(A)	30 874	6.9

Noise Map (road source) calculated with **CNOSSOS**
 Exposure population table
 Grenoble-Alpes Metropole - Revision 2019 acoucité

Lden road	Exposed population (inhabitants)	Exposed population (%)
Lden in dB(A)		
< 55	44 274	9.9
[55-60[	147 057	33.0
[60-65[	190 851	42.8
[65-70[	57 165	12.8
[70-75[	6 005	1.3
>=75	163	0.0
Total	445 515	100.0
Exceeding limit >=68 dB(A)	19 258	4.3

Table 2. Population exposure to road noise - NMPB08 vs CNOSSOS - Grenoble-Alpes Metropole 2019

In terms of distribution, the change in method (from NMPB08 to CNOSSOS) induces a decrease in Lden noise levels by an average of 1 dB(A), with 50% of the population affected by a reduction of 1 dB(A) or more (see Figure 3).

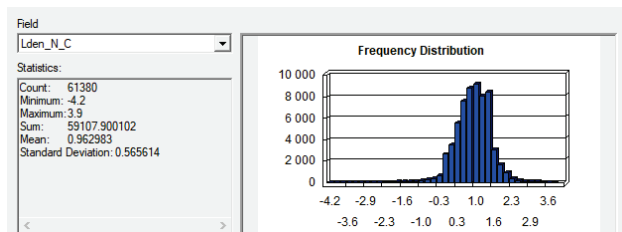


Figure 3. Statistics of evaluation “Lden (NMPB08) - Lden (CNOSSOS)” – CadnaA© software DataKustik – 2019

96% of the population is affected by decreases in Lden levels calculated at 2 meters from the most exposed facade of residential buildings.

2.5% of the population is affected by Lden levels calculated at 2 meters from the most exposed facade, higher using the CNOSSOS method.

Finally, for 1.5% of the population, no variation in the Lden levels calculated at 2 meters from the most exposed facade is observed.

3. HEALTH IMPACTS OF TRANSPORT NOISE

3.1 Context and Definition

Several epidemiological studies have shown that permanent exposure to noise can have health effects such as sleep disturbance, fatigue, decreased alertness, decreased work efficiency, and learning disabilities in children.

On the basis of this work, the World Health Organization (WHO) conducted international Europe-wide studies, "Burden of disease from environmental noise - Quantification of healthy life years lost in Europe" [5], in March 2011, then in October 2018 "Environmental Noise Guidelines for the European Region" [6].

For each recognized health impact of noise (in particular sleep disturbance, cardiovascular disease and annoyance), WHO has established a method to determine noise-related morbidity, i.e. the impact of noise-related health effect. Indeed, WHO uses a Disability-Adjusted Life Year (DALY) indicator, which quantifies the number of years of healthy life "lost" due to illness, disability or early death, in relation to the life expectancy of a group of individuals over a calendar year.

It is calculated in the following way (Figure 4), by adding:

- The years lived with the illness or disability;
- The years of life lost through early death compared to average life expectancy.



Figure 4. By Planemad – Own work, CC BY-SA 3.0, March 2012¹.

Acoucité worked on a methodology to calculate DALYs within a conurbation due to transport noise, based on the DALY quantification method proposed by WHO. A comparative study has also been conducted when the latest WHO guide was published with new recommendations, based on the latest knowledge on the effects of noise on health, in October 2018.

¹ https://commons.wikimedia.org/wiki/File:DALY_disability_affected_life_year_infographic.png

This work was carried out with the aim of anticipating the future requirements of Annex III of Directive 2002/49/EC [1], which states that “*dose-effect relations should be used to assess the effect of noise on populations*”.

The input data for these calculations are the tables of population exposure to transport noise from the SNMs.

The effects to be considered are:

- Annoyance (for road, rail and air traffic)
- Sleep disturbance (for road, rail and air traffic)
- Ischemic heart disease (for road traffic only)

3.2 Dose-effect relations

3.2.1 Annoyance caused by transport noise

Updated dose-effect relations have been established between exposure to a noise source and the Absolute Risk for High Annoyance (AR_{HA}). High annoyance is defined as the occurrence of annoyance in a population exposed to a specific level of transport noise (Figure 5).

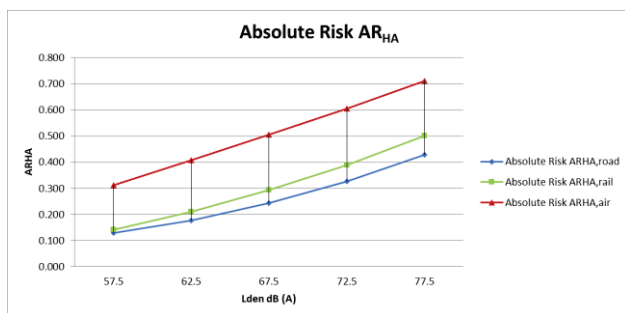


Figure 5. Dose-effect relation between absolute risk and noise level for the annoyance

The number of people highly annoyed by noise (NHA) depends directly on the absolute risk AR_{HA} and the number of people exposed to transport noise.

The number of DALYs can then be calculated from NHA, as well as a Disability Weight (DW) coefficient which reflects a more or less significant deterioration in health status and can vary from 0 (non-degraded health status) to 1 (death). For annoyance, $DW_{HA} = 0.02$.

3.2.2 Sleep disturbance due to transport noise

Updated dose-effect relations have been established between exposure to a noise source and the Absolute Risk for High Sleep Disturbance AR_{HSD} . This is defined as the occurrence of sleep disturbance in a population exposed to a specific level of transport noise.

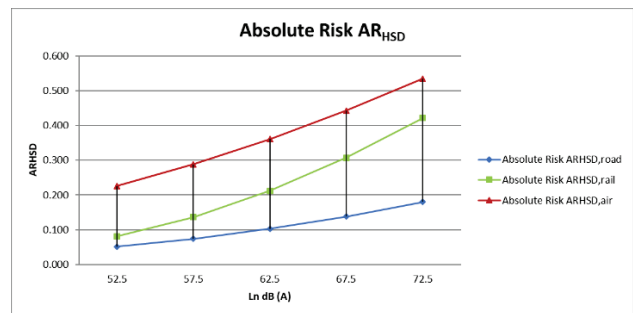


Figure 6. Dose-effect relation between absolute risk and noise level for sleep disturbance

The number of people with noise-induced sleep disturbance (N_{HSD}) depends directly on the absolute risk AR_{HSD} and the number of people exposed to transport noise at night.

The number of DALYs can then be calculated from N_{HSD} , as well as a DW coefficient which reflects a more or less significant deterioration in health status and can vary from 0 (non-degraded health status) to 1 (death). For sleep disturbance, $DW_{HSD} = 0.07$.

3.2.3 Ischemic heart disease due to transport noise

Epidemiological studies have shown an increase in ischaemic heart disease related to road noise exposure. While the relation between rail and air noises and ischaemic heart disease has been established, quantification of the increased risk of ischaemic heart disease is still premature for these two sources.

Updated dose-effect relations were established between exposure to a noise source and the relative risk $RR_{IHD,i}$ for ischaemic heart disease and incidence rate (i). The latter is defined as the quotient of the probability of occurrence of the disease in a population exposed to a specific level of noise by the probability of occurrence of the disease in a population not exposed to road noise.

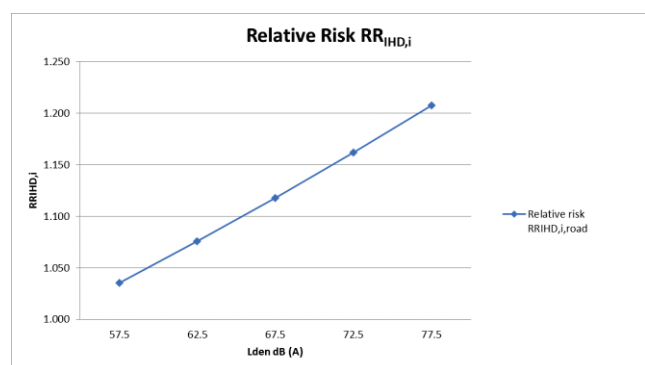


Figure 7. Dose-effect relation between relative risk and noise level for ischemic heart disease

For Ischemic Heart Disease (IHD), the number of people affected by $N_{IHD,road}$ noise directly depends of:

- The population attributable fraction ($PAF_{IHD,i}$), relative risk ($RR_{IHD,i}$) and population exposed to road noise;
- The incidence rate (i) of IHD in France;

- The total population exposed to road noise in the territory.

The number of DALYs can then be calculated from the $PAF_{IHD,i}$ as well as the rate of years lived with a health impairment YLD_{IHD} (Years Lost due to Disability) and the total number of population exposed to road noise.

3.3 Results for Lyon Metropole

The following results are based on the tables of population exposure to transport noise (road, rail and air traffic) from the SNMs carried out in 2018, calculated using the NMPB08 method (Round 3) on the 59 communes of the Lyon Metropole.

For air noise, there are no data for the indicator Ln in the population exposure tables. Therefore, sleep disturbance is only calculated with road and rail noises.

3.3.1 Number of people affected by the harmful effect

The number of people affected for each health effect and each noise source is distributed as follows:

Source	Annoyance	Sleep disturbance	Ischaemic heart disease	Total	Total %
Road	224 128	52 944	123	277 195	20.9%
Rail	33 334	15 701	/	49 035	3.7%
Air	40	/	/	40	0.0%
Total	257 501	68 646	123	326 270	24.6%
Total %	19.44%	5.18%	0.01%	24.6%	

Table 3. Number of people affected for each mode of transport and each health effect – Greater Lyon 2019

The main health effect is annoyance, with 257 501 people affected, i.e. 19% of the total population of the Lyon Metropole. Approximately 5% of the total population is affected by sleep disturbance and ischemic heart disease. Road noise alone affects 21% of people in the Lyon Metropole.

3.3.2 Number of DALY

In total, this represents 10 082 years of healthy life lost each year in the Lyon Metropole by the entire population.

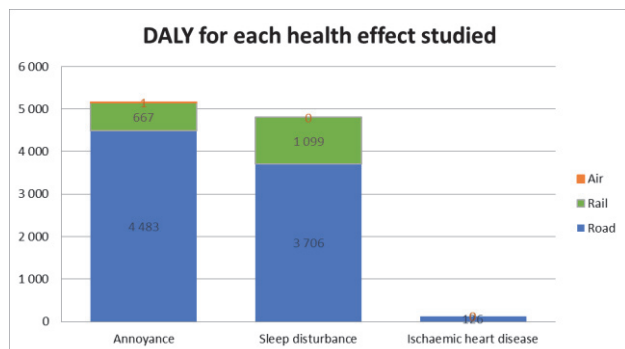


Figure 8. Disability Adjusted Life Years for each health effect studied – Greater Lyon 2019

The main health effect is annoyance with 5 150 years of healthy life lost, or 51% of DALYs, closely followed by sleep disturbance.

Source	Annoyance	Sleep disturbance	Ischaemic heart disease	Total
Road	4 483	3 706	126	8 315
Rail	667	1 099	/	1 766
Air	1	/	/	1
Total	5 150	4 805	126	10 082
Total %	51.08%	47.66%	1.25%	100%

Table 4. DALY for each mode of transport and each health effect – Greater Lyon 2019

Road noise alone generates 8 315 DALYs, i.e. 82% of the impacts of transport noise.

3.3.3 Statistical extrapolation for a lifetime

It is possible to estimate the period of healthy life lost due to transport noise over an individual's lifetime:

- From the average life expectancy between men and women (82.05 years according to INSEE 2015 data¹)
- Assuming for each individual, that he or she resides all his or her life in the Lyon conurbation and that his or her exposure to noise corresponds to the average of those of the inhabitants of the metropolis.

The calculation gives the result of 7.5 months lost on average over a lifetime for a single person.

3.3.4 Economic cost estimate

WHO recommends that €50,000 be used as the economic statistical value of a life year (VSly: Value of Statistical Life Year).

Applying this value to the territory of Greater Lyon, the economic costs of the burden of disease due to transport noise amount to nearly 500 million euros each year.

3.4 Results for Grenoble-Alpes Metropole

The following results are based on the tables of population exposure to transport noise (road and rail traffic) from the SNMs carried out in 2019, calculated using the CNOSSOS method (Round 3) on the 49 communes of Grenoble-Alpes Metropole.

3.4.1 Number of people affected by the harmful effect

The number of people affected for each health effect and each noise source is distributed as follows:

Source	Annoyance	Sleep disturbance	Ischaemic heart disease	Total	Total %
Road	67 877	18 249	35	86 161	19.6%
Rail	12 352	4 757	/	17 109	3.9%
Air	/	/	/	/	/
Total	80 230	23 006	35	103 270	23.5%
Total %	18.24%	5.23%	0.01%	23.5%	

¹ <https://www.insee.fr/fr/statistiques/2416631#tableau-Donnes>

Table 5. Number of people affected for each mode of transport and each health effect – Grenoble-Alpes Metropole 2019

The main health effect is annoyance, with 80,230 people affected, i.e. 18% of the total population of Grenoble-Alpes Metropole. About 5% of the total population is affected by sleep disturbance and ischemic heart disease. Road noise alone affects nearly 20% of people in the Metropolis of Grenoble-Alpes.

3.4.2 Number of DALY

In total, 3,251 years of healthy life years are lost each year in Grenoble-Alpes Metropole by the entire population. Comparatively, based on the population exposure results obtained with the NMPB08 method, the total number of DALYs obtained is 3,549 (i.e. 298 more).

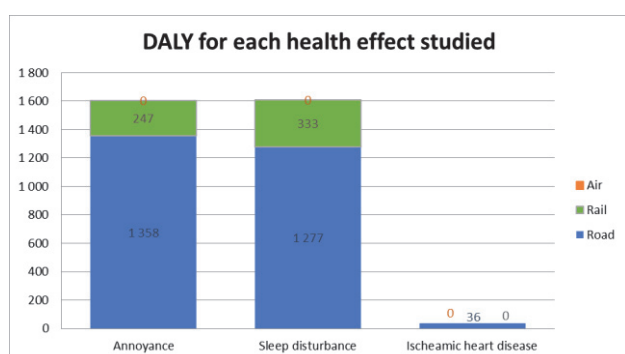


Figure 9. Disability Adjusted Life Years for each health effect studied – Grenoble-Alpes Metropole 2019

The main health effect is sleep disturbance with 1 610 years of healthy life lost, or 49% of DALYs, closely followed by annoyance.

Source	Annoyance	Sleep disturbance	Ischemic heart disease	Total
Road	1 358	1 277	36	2 671
Rail	247	333	/	580
Air	/	/	/	/
Total	1 605	1 610	36	3 251
Total %	49.36%	49.54%	1.11%	100%

Table 6. DALY for each mode of transport and each health effect – Grenoble-Alpes Metropole 2019

Road noise alone generates 2 671 DALYs, or 82% of the impacts of transport noise.

Using the population exposure results obtained with the NMPB08 method (applied only for road noise), it alone generates 2 969 DALYs (the 298 more), corresponding to 84% of the impacts of transport noise.

3.4.3 Statistical extrapolation for a lifetime

The estimation method is the same as for Lyon Metropole.

The calculation gives the result of a little over 7 months lost on average over a lifetime for a single person (the result is almost 8 months with the results obtained with the NMPB08 method).

3.4.4 Economic cost estimate

Applying VSLY to the territory of the Grenoble-Alpes Metropole, the economic costs of the burden of disease due to transport noise amount to nearly 160 million euros each year (175 million each year, with the results obtained using the NMPB08 method).

4. CONCLUSION

In order to evaluate the differences in calculated noise levels between the common method (CNOSSOS) currently in force and the former national method (NMPB08), for road noise, calculations were carried out on the territory of the metropolis of Grenoble using both methods, keeping the same input data (except for the breakdown into vehicle categories which differs) and the same calculation configuration parameters. The change of method (from NMPB08 to CNOSSOS) induces a decrease of the Lden noise levels by an average of 1 dB(A), with 50% of the population concerned by a reduction of 1 dB(A) or more, due to the integration of new vehicle categories (medium heavy vehicles and powered two-wheelers). This comparison was made before the requirements of Annex II §2.8 of the directive [1] were considered, concerning the distribution of receivers on the facades of residential buildings and the population.

Ongoing work is being carried out in our partner territories and in close collaboration with the Noise and Physical Agents Mission of the French Ministry of the Environment and two modelling software manufacturers, to assess the influence of this distribution on population noise exposure. This should also have an impact on the number of people affected by health effects (ischemic heart disease, annoyance and sleep disturbance), assessed from the SNM exposure tables. The health impacts presented in this article have been assessed in anticipation of the future requirements of Annex III, the text of which was recently adopted [7].

5. ACKNOWLEDGEMENTS

The authors would like to thank in particular the metropolises of Lyon and Grenoble, as well as the Mission Bruit et Agents Physiques of the French Ministry of the Environment and Cerema for their support and contribution to this case study.

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