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Mapping the health impacts of transport noise in the densely populated area of the Île-de-France region

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ABSTRACT

The European Noise Directive (END) requires agglomerations of more than 100,000 inhabitants to produce strategic noise maps. In the Ile-de-France region, 14 agglomerations with a total population of 10.5 million inhabitants are concerned.

Bruitparif applied the health impact assessment methodology recommended by the WHO to carry out a detailed territorial diagnosis of the issues related to transport noise. For this purpose, population exposure was assessed on the basis of strategic noise maps produced according to the 4th round of the END and the associated risks were calculated using the dose-effect relations published by the WHO in October 2018. The work continued with the valuation of healthy life years lost due to transport noise.

Two types of maps have been produced with a 200m x 200 m grid as well as at the municipal levels: maps of collective health impacts related to population noise exposure and maps of average individual risk corresponding to the potential impact per individual.

The combination of these two types of information makes it possible to highlight significant territorial disparities and to identify the sectors most concerned by the health issues related to noise, a prerequisite for prioritizing public action.

1. INTRODUCTION

Noise is a major source of annoyance in Ile-de-France region due to its high population density and its dense transport infrastructure. Noise is one of the main nuisances cited as impacting quality of life. Ile-de-France is the most populous region of France with 12.2 million inhabitants in a surface area of 12,000 km^2, mainly concentrated in the region's densely populated zone, which has a population of 10.5 million. Most of the exposure to noise is caused by transport infrastructures, which are very highly developed and dense.

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There is, therefore, great concern related to noise in Ile-de-France. According to the results of one survey on 3074 Ile-de-France residents [1], 78% of the population of Ile-de-France claim to be concerned about noise pollution (31% very concerned and 47% somewhat concerned), and 36% of residents believe that noise is a major disadvantage of living in Ile-de-France, almost as much as for air pollution (38%). 56% of Ile-de-France residents claim to be annoyed by noise at home, with this annoyance growing with the degree of urbanisation, on average 46% in the Seine-et-Marne which is rather a rural department and 67% in Paris city.

Thanks to various studies that have been published at international level, the health impact of noise is now well and truly established. It goes beyond just the annoyance caused. Beyond the effects on the auditory system observed for high noise levels, several extra-auditory effects have also been identified, including sleep disturbance, cardiovascular disease and diminished learning capacity. Studies have also shown that noise is a factor that reinforces social inequality, with underprivileged populations also generally being those most exposed.

To raise awareness of this major public health issue, we need to collect and publish quantified data for the region. That is why Bruitparif, the noise observatory for Ile-de-France region, has evaluated morbidity due to transport noise within the densely populated zone of Île-de-France.

2. STRATEGIC NOISE MAPS

The European Noise Directive (END) 2002/49/EC of 25 June 2002 [2] requires all agglomerations of more than 100,000 inhabitants to produce a strategic noise map for their territory and update it every five years, as well as adopting an environmental noise action plan. The noise sources taken into account are those related to road, rail, and airport infrastructures, as well as industrial facilities. Within the Ile-de-France region, 14 agglomerations representing a total of 433 municipalities and 10.5 inhabitants are concerned: the Greater Paris Metropolis (131 municipalities, 7 million inhabitants) as well as 13 other agglomerations (cf. Figure 1).

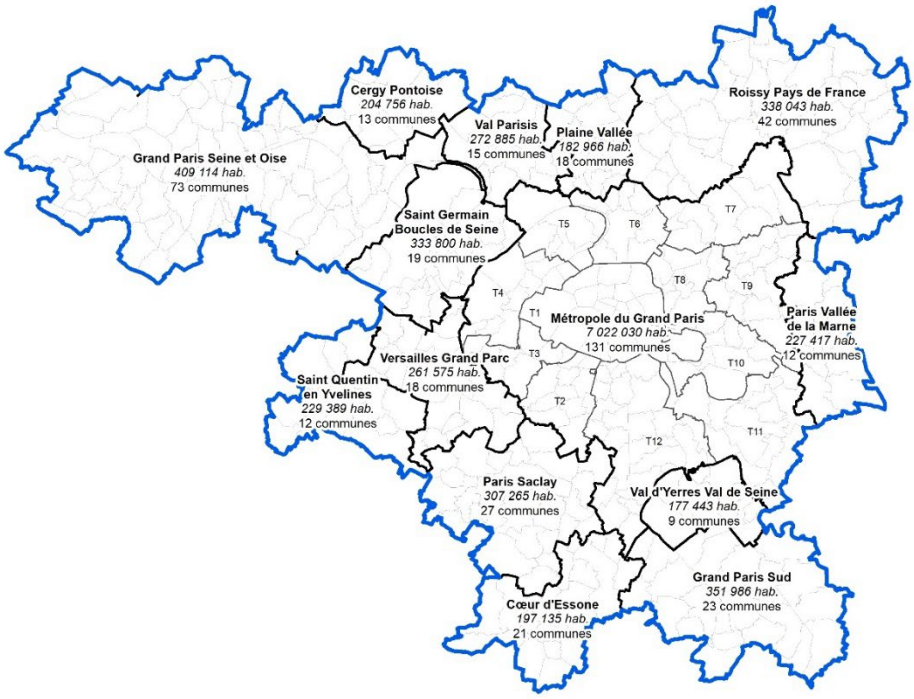


Figure 1: The 14 agglomerations representing the densely populated zone of Ile-de-France region.

The so-called fourth-phase strategic noise maps (see Figure 2) were produced and supplied in 2023 by Bruitparif to each of the 14 agglomerations, with a view to their approval and publication. These strategic noise maps must also serve as a reference document for these local authorities to prepare their environmental noise action plans. To this end, and in order to help identify key priorities, Bruitparif has realized an additional territorial diagnostic to evaluate the health impact of transport noise within each of the 14 agglomerations that make up the densely populated zone of Ile-de-France.

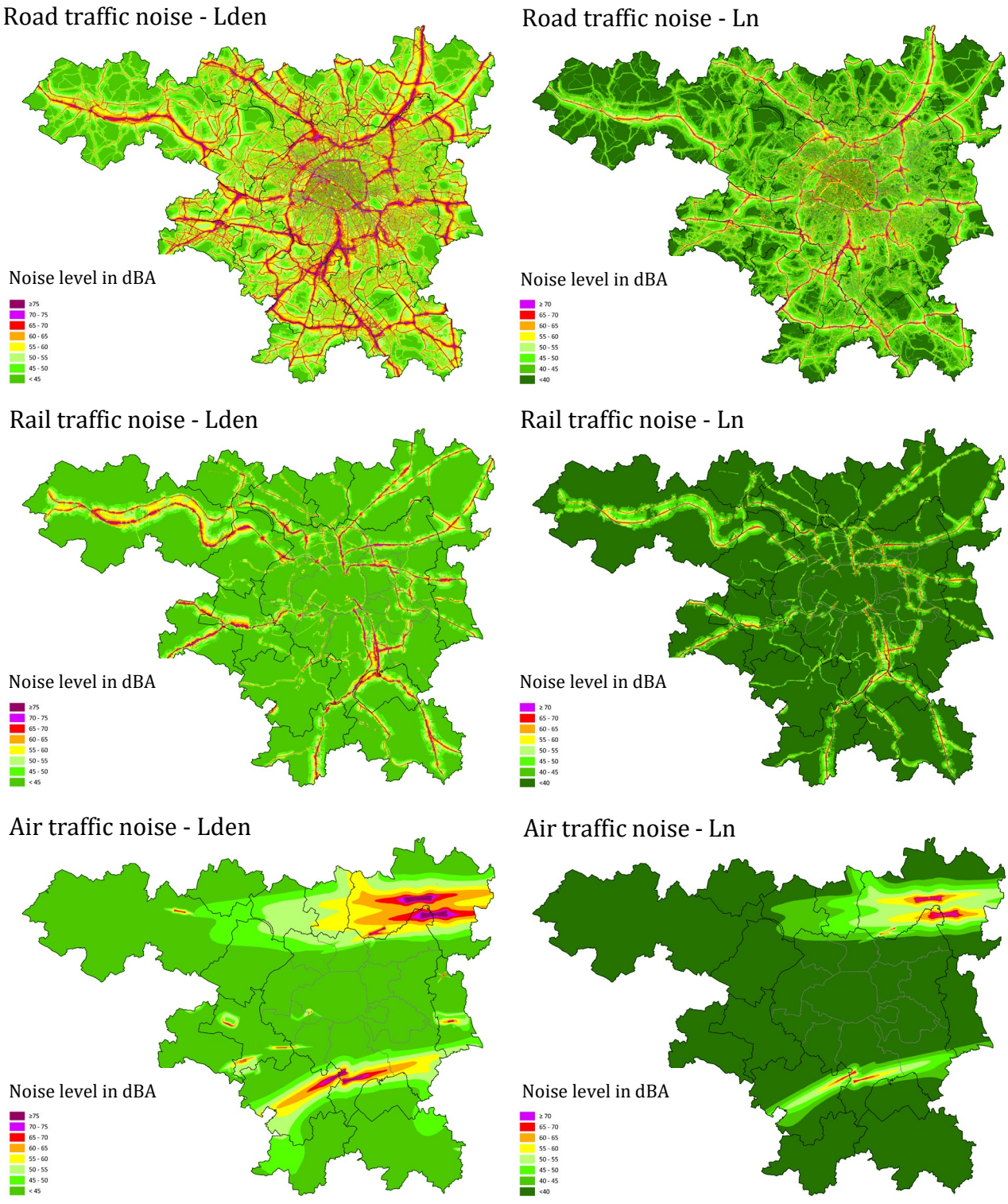


Figure 2: Strategic noise maps for the densely populated zone of Ile-de-France region (14 agglomerations).

3. METHODOLOGY

Bruitparif used the methodology recommended by the World Health Organisation (WHO), based on the indicator of healthy life-years (DALY - Disability-Adjusted Life-Years) lost [3;4;5], as well as the guidelines on environmental noise published by the WHO in October 2018 [6].

3.1. Recognised health impact of noise

Based on a wide review of the scientific literature, the WHO claims in October 2018 that there are robust and proven dose-effect relations between populations' levels of exposure to noise and the rates of people who claim to be highly annoyed or have highly disturbed sleep. Figure 3 shows the dose-effects relations available for these health effects for the three different sources of transport noise.

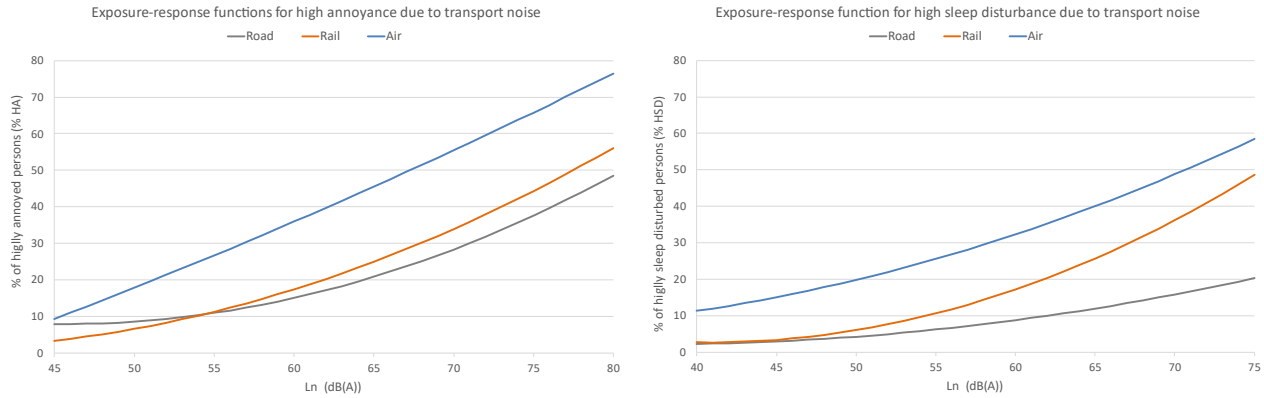


Figure 3: Dose-effects relations for high annoyance (left graph) and high sleep disturbance (right graph) due to transport noise.

Other health effects of noise are considered critical by the WHO, in particular cardiovascular risk (coronary heart disease, high blood pressure, myocardial infarction) and learning difficulties. However, we do not currently have sufficiently robust dose-effect functions for these three sources of transport noise. Cardiovascular risk, for example, is relatively well described for exposure to road noise but not yet sufficiently for rail and aircraft noise. As for learning difficulties, the available studies have mainly focused on young student populations subjected to aircraft noise pollution. For questions of homogeneity and coherence in the consideration of different noise sources in this study, Bruitparif chose to only process the two best-documented effects, namely high annoyance and high sleep disturbance.

3.2. Noise indicators

The levels of exposure to noise used for these dose-effects relations are expressed using the indicators used in the strategic noise maps, namely Lden (noise weighted over 24h) and Ln (night-time noise, night-time period is 10 PM-6 AM in France). The Lden indicator (which stands for Level day evening night) is an indicator of overall noise over 24 hours which takes into account the fact that sensitivity to noise is higher in the evening and at night. The Lden indicator is calculated using equivalent average noise levels (LAeq) during the day (6AM-6 PM), in the evening (6 PM-10 PM), and at night (10 PM-6 AM) applying a weighting of +5 dBA and +10 dBA to noise in the evening and at night. It is calculated as an average over the year. The Ln indicator (Level night) is the average noise over the night-time period (10 PM-6 AM). It is calculated as an average over the year as well.

3.3. Reference values

To protect the health of populations, the WHO published in October 2018 guidelines concerning environmental noise, strongly recommending reducing exposure to transport noise to the levels indicated in Table 1 below. The WHO's recommendations must be considered as targets to reach in order to minimise the adverse effects of noise on populations.

Table 1: Transport noise recommendations by WHO (2018).

	Lden dBA	**Ln dBA**
Road	53	45
Rail	54	44
Air	45	40

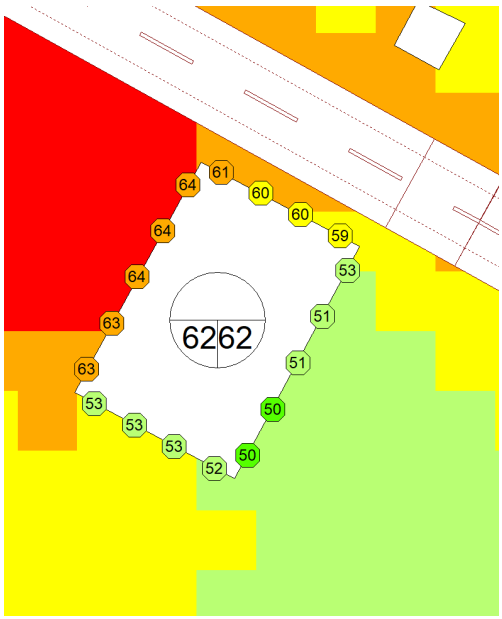
France adopted regulatory limit values based on the framework of the transposition of European directive 2002/49/EC. The limit values set by France are as follows:

Table 2: French regulatory limit values for transport noise.

	Lden dBA	**Ln dBA**
Road	68	62
Rail (conventional)	73	65
Rail (high speed)	68	62
Air	55	50

3.4. Noise exposure assessment

For the fourth round of strategic noise maps, the assessment of the exposure of people living in dwellings to noise has been made according to the common noise assessment method (CNOSSOS-EU) [7] based on noise assessment points at 4 m above ground (receiver points). This method introduced a major change compared with previous rounds of the END during which the most highly exposed receiver point around a building was attributed to all the inhabitants of that building. For the fourth round, this method only applies for aircraft noise and, for land-bases noises sources, to individual housing or when the distribution of dwellings or inhabitants in the building is known. For other dwellings, the set of associated receiver locations have been split into a lower and upper half based on the median value of the calculated assessment levels for each building. For each receiver point in the upper half of the data set, people living in dwellings have been distributed equally (see Figure 4).



RECEIVER	NOISE LEVEL LDEN	NUMBER OF PEOPLE
1	49.1	0
2	49.4	0
3	50.7	0
4	51	0
5	51.7	0
6	52.4	0
7	52.5	0
8	52.6	0
9	53	0
10	58.7	6.89
11	59.2	6.89
12	59.9	6.89
13	60.8	6.89
14	62.2	6.89
15	63	6.89
16	63.6	6.89
17	63.9	6.89
18	64.1	6.89

Figure 4: Example of assessment of the exposure of people living in dwellings (here 62 inhabitants) to noise for road traffic noise, with the median method.

3.5. Disability adjusted life-years (DALY) lost values

Based on the exposure data of people to noise expressed using the Lden and Ln indicators, it was possible to calculate the number of people affected by high annoyance and by high sleep disturbance at a 200 m grid resolution as well as at the municipality level, using the noise dose-effect relations established.

Calculations have been made for noise exposure levels above 45 dBA Lden and 40 dBA Ln, the noise dose-effect relations for high annoyance and for high sleep disturbance being deemed valid from these values onwards for the three noise sources.

The numbers of people affected by these adverse effects of noise were then converted into healthy life-years (disability-adjusted life-years, DALY) lost. The DALY is a metric recommended by the WHO to quantify the deterioration of populations' health due to disease or by exposure to environmental factors. The WHO estimates that high annoyance can be translated by a health deterioration coefficient (also called disability weight) of 0.02, and high sleep disturbance by a disability weight of 0.07. The disability weights related to each health impact vary on a scale of 0 (undeteriorated health) to 1 (death). They were calculated based on expert opinions collected by the WHO.

4. MAIN RESULTS

A certain number of results regarding the population's exposure to transport noise and its health impact were produced in the form of maps and statistics.

It was decided to present the results by noise source (road noise, rail noise, and aircraft noise) and cumulatively for the three sources. For each source, after a reminder of the main results from the strategic noise maps (population distribution by range of noise level and comparison with the different reference values), the health impacts are presented. The values of disability-adjusted life-years lost due to high annoyance and high sleep disturbance were added, at the resolution of the 200 m grid as well as at that of the municipality.

Two types of maps are provided for each territorial unit, for each noise source as well as for the three sources cumulatively: a map showing the total number of disability-adjusted life-years lost each year and a map showing the average individual risk (healthy life-months lost per individual over a lifetime).

These two types of information seem complementary in terms of the selection of the territory's priority sectors. The map of disability-adjusted life-years lost per territorial unit provides information on the collective scale of noise health impact, whereas the map of healthy life-months lost at individual level over a lifetime represents the individual risk.

Then, the results were compared with those obtained during the previous evaluation based on strategic noise maps produced according to the third round of the END, conducted in 2019 [8] by Bruitparif.

Finally, sensitivity tests were carried out on the variation in health impact results with the way in which people exposed to noise were counted.

4.1. Regarding exposure above the reference values

People within the densely populated zone of Ile-de-France region are highly exposed to transport noise since 86% of inhabitants (9 million people) are exposed to noise levels that exceed those recommended by the WHO to avoid the health effects of noise. This trend can be seen through the many people who are subjected to noise levels that exceed the regulatory limit values for France in application of the END: 1.5 million inhabitants (14.2% of the population) are exposed to noise levels that exceed at least one limit value for the Lden indicator.

Road traffic is the main cause, with 8.6 million inhabitants (81.6%) exposed over the WHO recommendation and 1 million inhabitants (9.7%) exposed over the French limit value for Lden indicator. At night, noise levels generated by road traffic are falling. However, 75.5% of the population (7.9 million inhabitants) still lives in accommodation exposed to outside road traffic noise levels that exceed the recommendation set by the WHO and 402,000 residents (3.8% of the population) are even concerned by night-time levels that exceed the regulatory limit value.

Exposures to aircraft noise and rail traffic noise are down but these two types of nuisances have proportionally higher health risks due to their event-related nature (succession of noise peaks). Aircraft noise affects a significant proportion of the territory. 19% of the population, or 2 million people, are exposed to noise levels in excess of 45 dBA according to the Lden indicator, considered by the WHO to be the quality objective to be achieved in order to avoid adverse health effects. 474,000 people, or 4.5% of the population of the densely populated Ile-de-France area, are exposed to noise levels in excess of the regulatory limit value of 55 dBA according to the Lden indicator. At night, exposure to aircraft noise decreases, particularly around Paris-Orly airport, which has a curfew between 11.30pm and 6am. However, 9.8% of the population still lives in a home exposed to an air traffic noise level of more than 40 dBA, considered by the WHO to be the quality objective to be achieved at night. Nearly 191,000 people (or 1.8% of the population) would even be affected by night-time levels that exceed the French regulatory limit of 50 dBA according to the Ln indicator. Even around Paris-Orly airport, nearly 13,000 people are subject to noise levels that exceed 50 dBA on average between 10pm and 6am, due to the nuisance generated by overflights between 10pm and the start of the curfew at 11.30pm.

In the densely populated Ile-de-France region, 9.6% of the population, i.e. one million people, are exposed to levels exceeding 54 dBA Lden at the front of their homes, i.e. above the level considered by the WHO to be the quality objective to be achieved in order to avoid the harmful health consequences of railway noise. And around 39,000 people, or 0.4% of the population, would exceed the regulatory limit values according to the Lden indicator, i.e. 73 dBA for conventional lines and 68 dBA for high-speed lines. At night, rail noise levels fall along passenger lines, but can still be significant, particularly near freight lines. As a result, around 35,000 people (0.3%) would be living in a situation where the French regulatory limit values are exceeded according to the Ln indicator (65 dBA for conventional lines and 62 dBA for high-speed lines).

4.2. Regarding health impact

Figure 5 provides the maps showing the total number of disability-adjusted life-years lost each year at the 200 m grid resolution (on the left) and at the municipality scale (on the right), for the three sources of transport noise cumulatively.

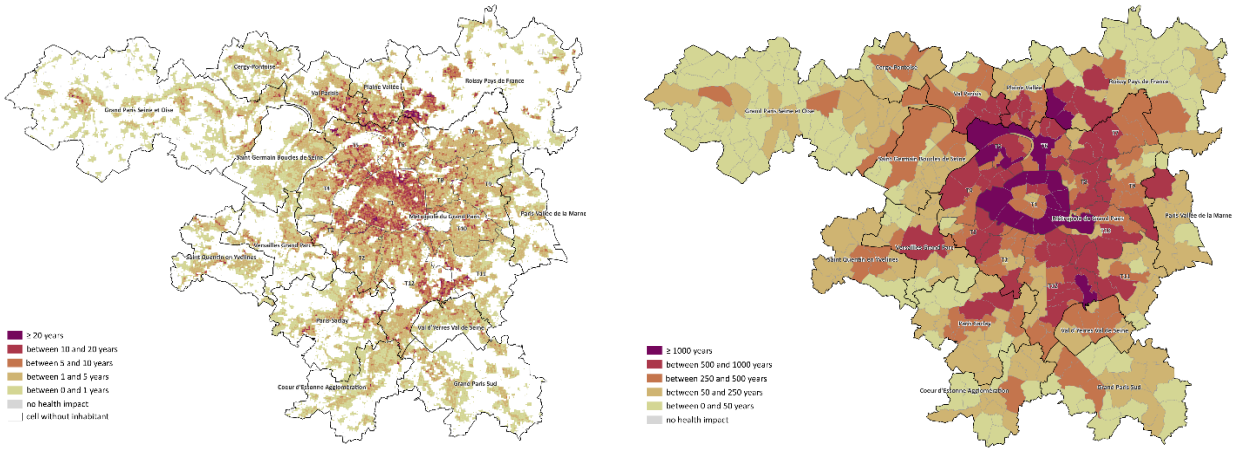


Figure 5: Cumulated transport noise collective health impact - number of healthy life-years lost per year - grid of 200 m (left) - municipality level (right).

In total, in terms of the health impact, transport noise is responsible for the loss of 99,200 disability-adjusted life-years (DALY) every year within the densely populated zone of the Ile-de-France region (cf. table 3), distributed between the DALY lost due to high annoyance (46,266, 47% of the total) and the DALY lost due to high sleep disturbance (52,934, 53% of the total). Road noise is responsible for 66% of the health impact (65,930 DALY), followed by aircraft noise (19,124 DALY, 19%), and railway noise (14,146, 14%).

Table 3: DALY in in the densely populated area of the Île-de-France region.

DALY	Road	Rail	Air	Total
HSD	33,589	8,176	11,169	52,934 *(53%)*
HA	32,341	5,970	7,955	46,266 *(47%)*
Total	65,930 *(66%)*	14,146 *(14%)*	19,124 *(19%)*	99,200

Most of the municipalities with the highest numbers of healthy life-years lost due to cumulated transport noise (TOP30) are municipalities that have a high number of inhabitants and a high concentration of roads but there are also municipalities that combine densely populated areas and significant aircraft noise (cf. Figure 6). The municipality with the highest score (Argenteuil) is the one with the highest population density in the Ile-de-France region and which is exposed to all three sources of noise.

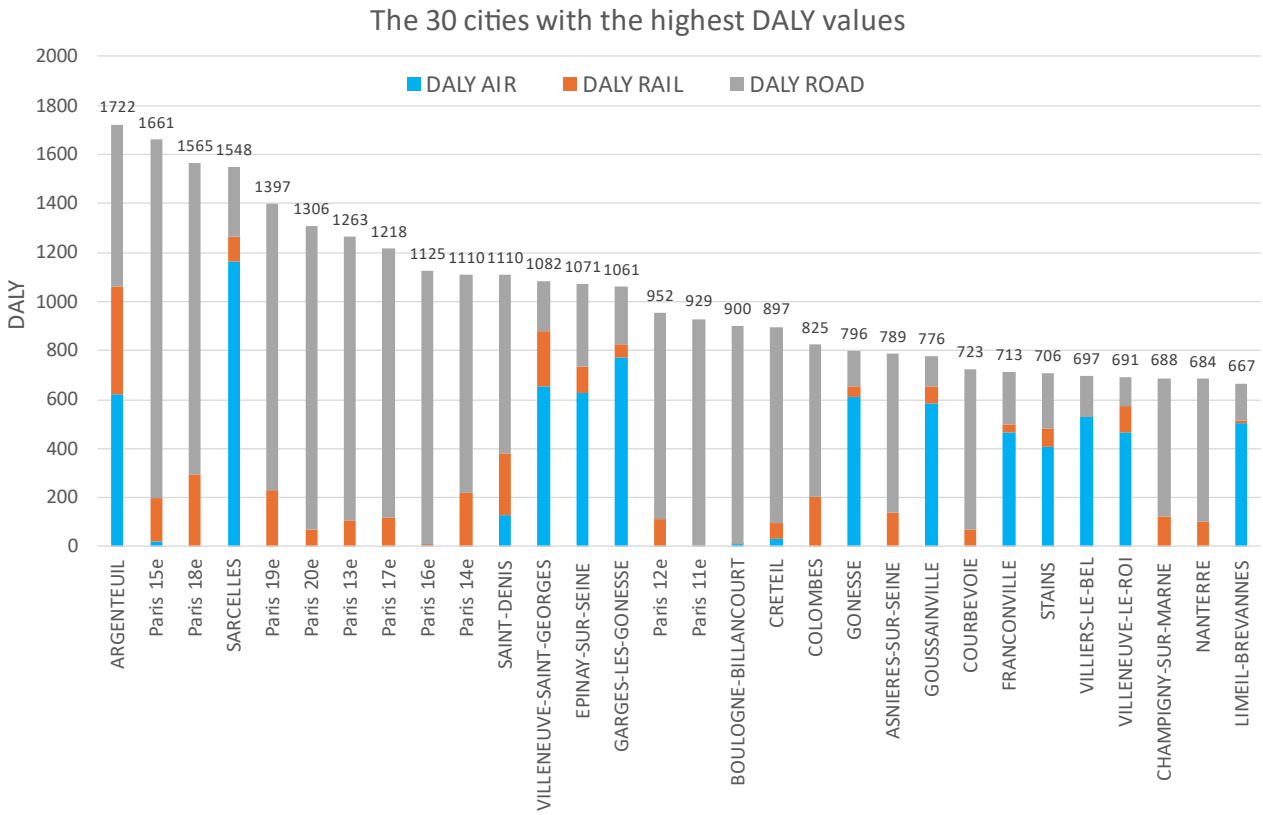


Figure 6: The 30 cities that have the highest DALY values.

Figure 7 provides the maps showing the average individual risk (healthy life-months lost per individual over a lifetime), at the 200 m grid resolution (on the left) and at the municipality scale (on the right), for the three sources cumulatively.

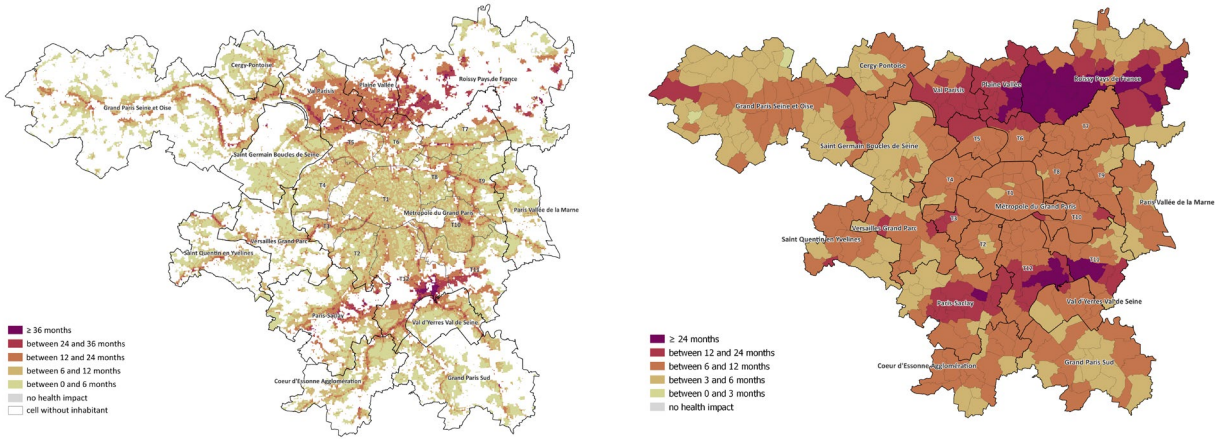


Figure 7: Cumulated transport noise individual health risks - number of healthy life-months lost per individual during a lifetime - grid of 200 m (left) - municipality level (right).

At individual level, the evaluations show an average statistical value of 9.4 healthy life-months lost during a lifetime per individual (i-DALY) due to cumulated transport noise, within the densely populated zone of Ile-de-France. There are, however, significant variations within the region, with the impact on healthy life-months lost per inhabitant ranging from 2.7 months to 35.3 months depending on the municipality. These significant variations highlight the impact of aircraft noise (see Figure 8).

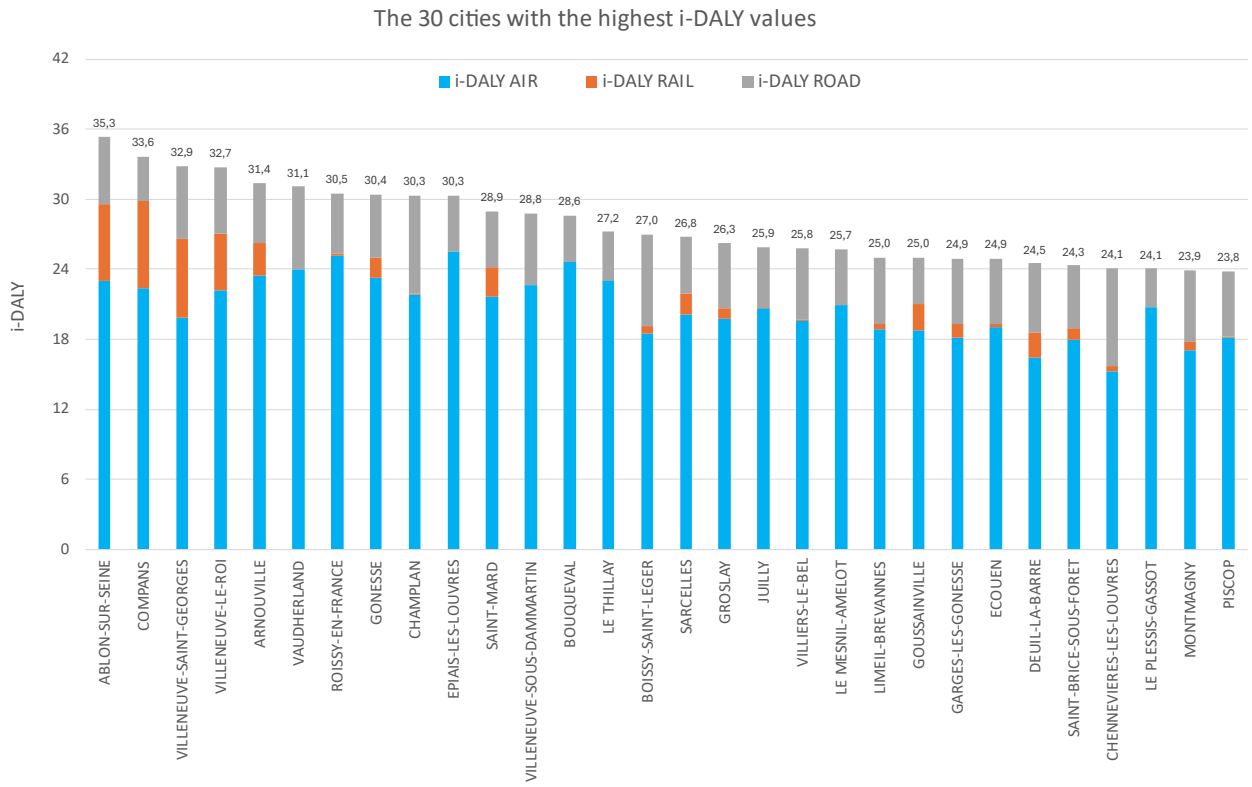


Figure 8: The 30 cities that have the highest i-DALY values.

4.3. Comparison with the previous evaluation

These results have been compared (see Table 4) with the previous evaluations carried out by Bruitparif in 2019 which were based on strategic noise maps produced according to the third round of the END. Estimations have been reviewed slightly downwards (from 107,766 to 99,200 DALYs, -8%). This is mainly due to the sharp fall in exposure to railway noise (-40%), as a result of the changes in railway noise modelling method and in the assessment method for people exposure brought about by CNOSSOS-EU.

Table 4: DALY in in the densely populated area of the Île-de-France region for the 2019 and 2024 evaluations

DALY	Road	Rail	Air	Total
2019	65,607	23,440	18,718	107,766
2024	65,930 *(+0.5%)*	14,146 *(-40%)*	19,124 *(+2%)*	99,200 *(-8%)*

4.4. Sensitivity tests

Two sensitivity tests for calculating health impacts were carried out.

The first sensitivity test concerned the thresholds at which the exposed populations are considered. The method used in the present study (thresholds of 45 dBA Lden and 40 dBA Ln for the three noise sources) was compared with two other approaches:

- Thresholds corresponding to the WHO's recommendation values for each noise source - see Table 1.

- Thresholds above which it is compulsory to produce noise maps in accordance with the END, i.e. 55 dBA Lden and 50 dBA Ln for the three noise sources.

Table 5 gives the results in DALY for the different methods of setting thresholds to start considering noise exposure, and the % deviation from the method used in the study.

Table 5: DALY in in the densely populated area of the Ile-de-France region depending on the thresholds to start considering noise exposure.

Thresholds	**DALY**			
	Road	**Rail**	**Air**	**Total**
45 dBA Lden and 40 dBA Ln (method used in the study)	65,930	14,146	19,124	99,200
WHO recommendation values	61,556 *(-7%)*	11,106 *(-21%)*	19,124 -	91,787 *(-7%)*
EU directive thresholds (55 dBA Lden and 50 dBA Ln)	58,159 *(-12%)*	9,557 *(-32%)*	7,817 *(-59%)*	75,533 *(-24%)*

It appears from this analysis that the thresholds from which exposure to noise is considered are an important factor in the sensitivity of the results, especially for rail traffic noise and air traffic noise. It seems preferable to consider exposure to noise from the WHO recommendations or even from the thresholds of validity of dose-effect relations in order not to underestimate the health impacts of noise.

The second sensitivity test focused on the level of precision of the population's noise exposure. Two methods were compared:

- The precise method used in the present study which consists of assigning each inhabitant to a noise level with dBA precision and then applying the dose-effect relations directly with these noise exposure levels.
- The approximate method which is proposed in France for calculating health impacts as requested by the Commission directive 2020/367 of 4 March 2020 amending Annex III to END. This method amounts to affecting populations in 5 dBA wide noise bands and then applying the dose-effect relations using the center of each noise band for calculation (example: 62.5 dBA for the 60-65 dBA noise band).

Table 6 gives the results in DALY of the two methods applied to two different cases of thresholds to start considering noise exposure.

Table 6: DALY in the densely populated area of the Ile-de-France region depending on the level of precision of the population’s noise exposure.

Thresholds	**Level of precision**	**DALY**			
		Road	**Rail**	**Air**	**Total**
45 dBA Lden and 40 dBA Ln	Precise method	65,930	14,146	19,124	99,200
	Approximate method	66,325 *(+0.6%)*	14,308 *(+1%)*	20,586 *(7%)*	101,220 *(+2%)*

Thresholds	Level of precision	DALY			
		Road	Rail	Air	Total
EU directive thresholds 55 dBA Lden and 45 dBA Ln	Precise method	58,159	9,557	7,817	75,533
	Approximate method	52,041 *(-11%)*	8,590 *(-10%)*	6,336 *(-19%)*	66,967 *(-11%)*

It appears from this analysis that the precision on the level of exposure to noise has relatively little influence (+2%) on the result of the total health impact when we consider exposures from 45 dBA Lden and 40dBA Ln. On the other hand, this has a significant influence if we only consider exposure levels above 55 dBA Lden and 50 dBA Ln. This leads indeed to an underestimation of the health impact on average of 11% in total, and of 19% for air traffic noise. This calls for aiming for the best possible precision in noise exposure assessments.

6. CONCLUSION

With nearly 100,000 disability-adjusted life-years lost every year within the densely populated zone of Île-de-France, the results obtained confirm that noise pollution is the second-highest cause of morbidity among environmental risk factors in urban environments, behind atmospheric pollution.

Adjusted to the level of an average citizen living within the densely populated zone of Île-de-France, healthy life-months lost over a lifetime reach 9.4. Regional differences are also significantly exacerbated, with the individual health risk reaching three healthy life-years lost in sectors that suffer from exposure to multiple aircraft and land sources.

The study conducted by Bruitparif aims to fully contribute to anticipating where to focus resources in the fight against noise pollution, by creating a reference document to help stakeholders prepare the environmental noise action plans that the competent authorities will have to produce in 2024, according to the fourth-round of the END.

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