Noise generated by the ring road: state of knowledge and issues

With over 100000 inhabitants along its 35 km, the ring road is one the noisiest axes of Paris according to the noise maps of the City of Paris. Due to its popularity, and congested at regular hours, the ring road allows one quarter of all Paris traffic and represents an important link between Paris and the surrounding towns. In order to better understand the reality of these nuisances, BruitParif led a measurement campaign for one month in 2009 as well as a number of further studies in 2010/2011. The monitoring went on with the setting up of permanent measurement stations enabling to follow the evolution of noise levels over time and to quantify the impact of the measures which could be implemented. Here are presented the main results of these studies.

I. Strategic maps of noise

Within the framework of the implementation of the European directive 2002/49/CE, the City of Paris produced and published maps of noise on its website on June 30th, 2007. These maps were created by modeling, out of traffic and topography data (taking into account relief, buildings, screens...) and they offer annual average noise levels, through the use of two indicators that have been harmonized on a European level.

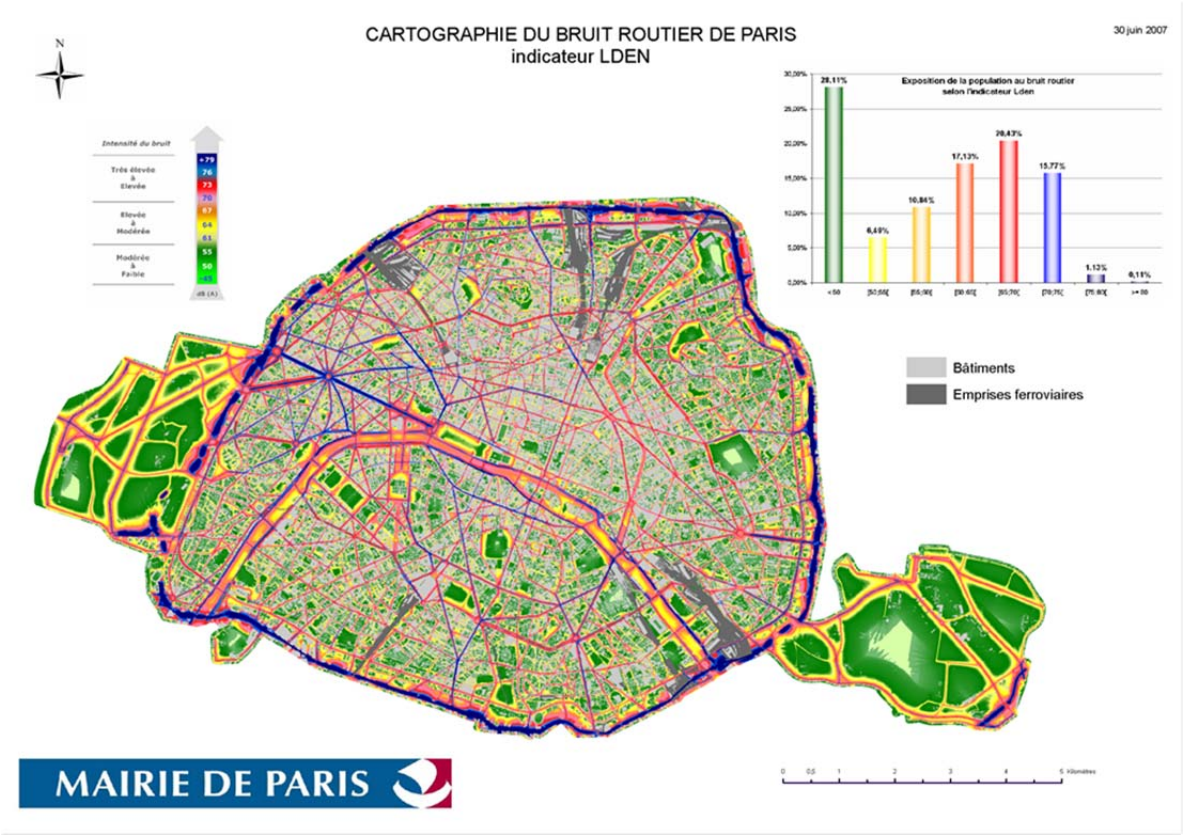
- the Lden indicator qui represents an average level of noise over the day, taking into account a weighting of +5dB (A) for evening levels (between 6pm and 10 pm) and +10 dB (A) for night levels so as to take into account the increased sensitivity to noise of inhabitants at these periods.
- the Ln indicator which represents the average levels of noise over nighttime (10 pm to 6 am)

These maps enable us to identify rapidly axes involving serious issues from the point of view of noise. This is obviously the case of the ring road which generates levels that can reach or exceed 80 dB(A) according to the Lden indicator, et 75 dB(A) according to the Ln indicator.

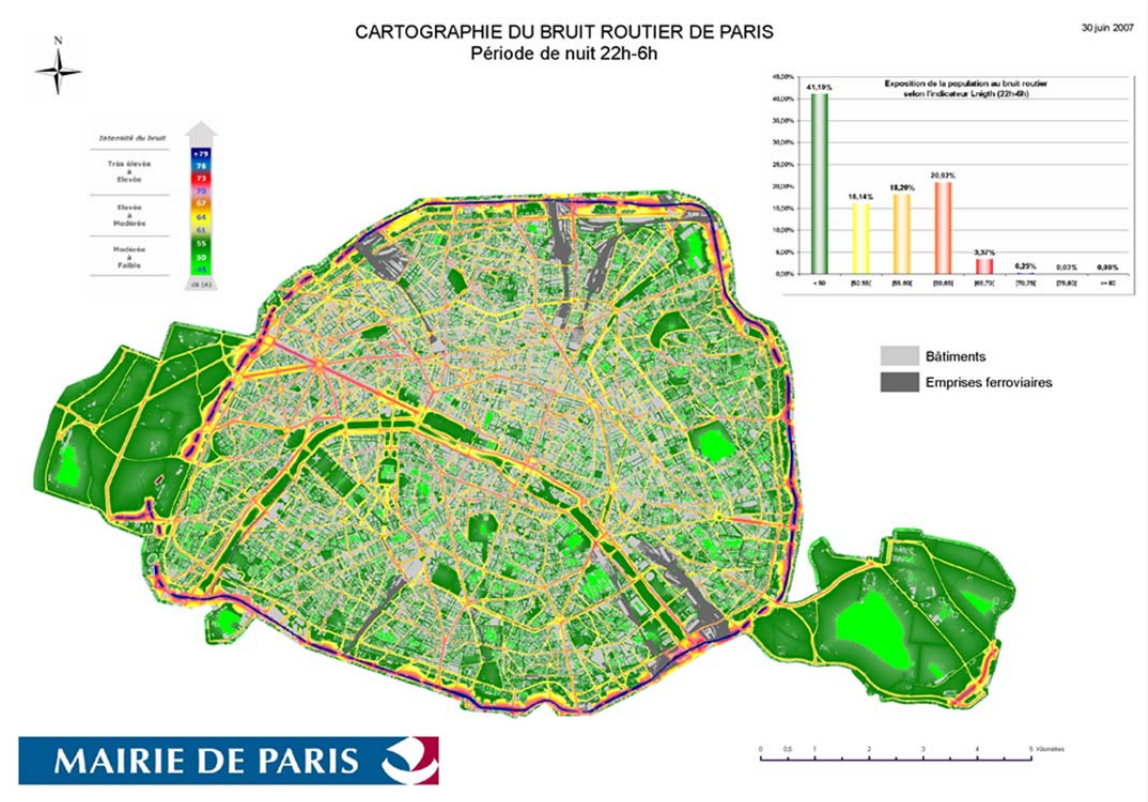
Moreover, these maps allow us to estimate the distribution of Parisians according to their potential exposure to noise (assessed according to the most exposed front of their lodgings). Limit values have been issued by France: 68 dB(A) for the Lden indicator and 62 dB(A) for the Ln indicator. The use of these maps thus allows us to estimate the proportion of inhabitants exposed beyond these limit values. In the case of Paris, this proportion rises to 25 % for the Lden indicator, and to 16 % for the Ln indicator, according to the exposure statistics collected by the City of Paris (cf table below)

		En dB(A)							
		< 50	[50;55[	[55;60[	[60;65[	[65;70[	[70;75[	[75;80[	>= 80
Période	Jour	32,0%	7,9%	15,8%	18,8%	20,4%	5,0%	0,2%	0,0%
	Soirée	32,0%	7,9%	15,8%	18,8%	20,4%	5,0%	0,2%	0,0%
	Nuit	41,1%	16,1%	18,2%	20,9%	3,4%	0,2%	0,0%	0,0%
	L_{den}	28,1%	6,5%	10,8%	17,1%	20,4%	15,8%	1,1%	0,1%

Noise exposure of the Paris population: statistics
(source: technical report noise maps published on June 30th by the City of Paris)



Mapping of Paris traffic noise (LDEN indicator)



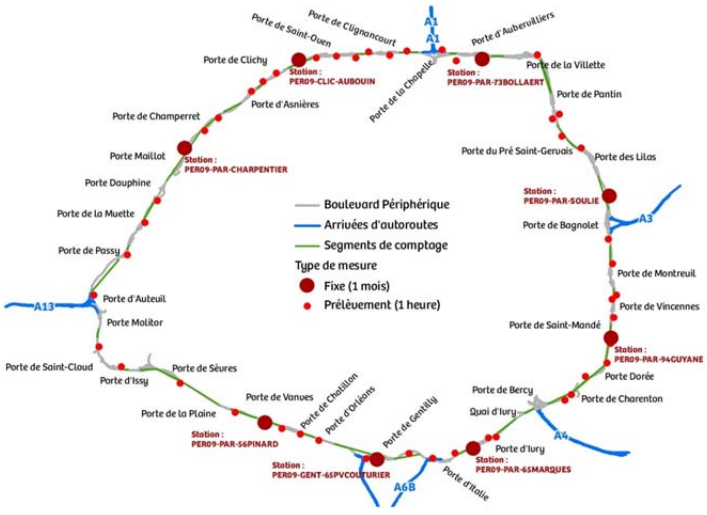
Mapping of Paris traffic noise (night time : from 22.00 to 06.00)

II. The campaign of noise measurement implemented in 2009

Strategic noise maps offer a spatial image of the sound environment around the ring road, but they do not allow to describe variations of noise over time, nor sudden irruptions (car horns, particularly noisy two-wheeled motorcars…) Such aspects are however at the heart of residents' concerns, and raise manifold questions :

- -what are the noisiest or the quietest moments?
- -what relationship between noise, traffic conditions (flows, speed, saturation, traffic composition) and the lay-out of the place (ring road embanked or entrenched in relation to the lodgings, presence of anti-noise screens, impact of side lanes…)
- -what are the dynamics of noise and what is the contribution of emerging sounds(horns, sirens, two-wheeled vehicles)?

In order to address such issues and to complete the strategic maps of noise made by the city of Paris and the 21 surrounding towns in the Haut-de-Seine, Saint- Denis and Val-de-Marne departments, Bruitparif launched a large campaign of measurements around the ring road. At the heart of the system, 8 fixed stations of noise measurement recorded traffic-generated noise near resident housing on each side of the ring road for 24 hours a day, second by second. In order to complete this system, a laboratory vehicle, equipped with innovative technologies and energetically self-sufficient thanks to its onboard solar panels, collected about 50 one-hour samples, or one sample every 700 meters. The idea was to have a homogenous spatial distribution of measurement points around the ring road and to have at hand a permanent station on the sections located between the large highway interchanges.

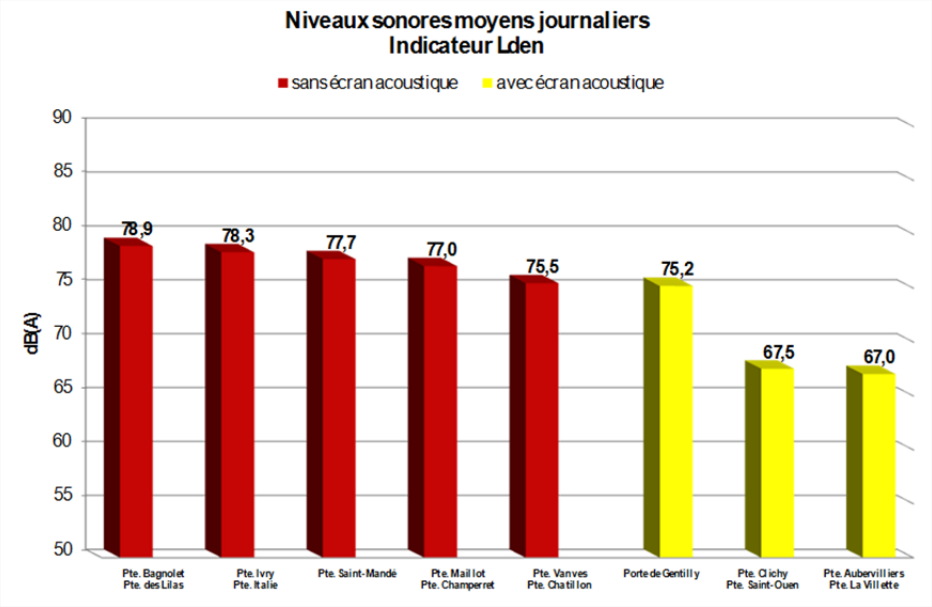


Map of samplings for the measurement campaign around the ring road (8 permanent fixed stations and 49 punctual samplings made from the laboratory vehicle)

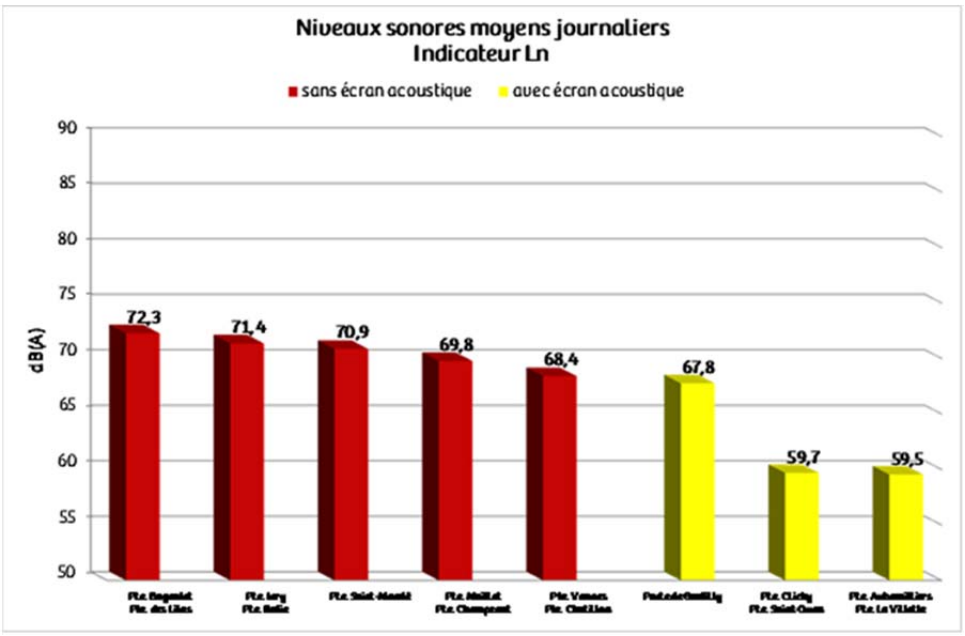
Different lessons were learned from this measurement campaign.

II. 1 Very high noise levels

The sound levels around the ring road are extremely high and regularly exceed the regulatory limits by night and by day when no noise control has been set up. Thus, concerning the Lden indicator, one can see that sites without noise control all present values largely beyond the regulatory limit values (between +7.5 and +10.9 dB(A) over 68 dB(A). And these is also the case for the Ln indicator. Sites without sound screens all offer values largely beyond the nightly limit value. Two sites out of three benefiting from a sound screen are slightly under these thresholds.



Noise levels of the Lden Indicator for the 8 fixed stations
Average daily noise levels Lden Indicator.
Red : Without a sound screen Yellow : With a sound screen



Noise levels of the Ln Indicator for the 8 fixed stations Average daily noise levels Ln Indicator. Red : Without a sound screen
Yellow : With a sound screen

II.2 Results which back up and complete the values drawn from the modeling

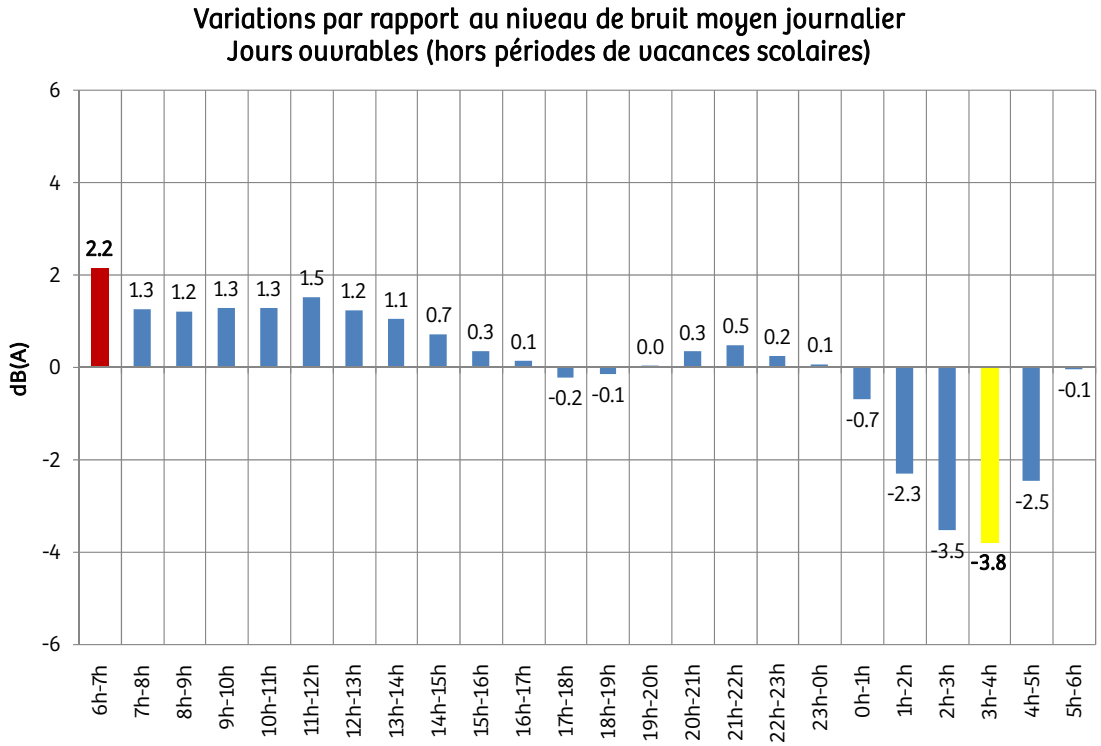
The results of the measures have been compared with the values of the map of noise created by modeling by the city of Paris within the framework of the implementation of the European directive 2002/49/CE.

Globally, for most of the sites involved, a good correspondence between the results of the measurements and the digital simulation has been observed. Thus, 73.5 % and 75.5% respectively of the sites offer deviations below or equal to 5 dB(A). The average deviations between the map results and the measurements are relatively low: +1.4 dB(A) for the Lden indicator and +0.8 dB(A) for the Ln indicator, which proves that the map matches the measurements on the whole, with a tendency of the modeling to overestimate values : in 82% of the studied sites for the Lden indicator and 69% for the Ln indicator, the values drawn from the strategic map of environmental noise are higher than the values measured on site.

Sites with a deviation above 5 dB(A) have been further analyzed. For the main part, the deviations result from imperfectly taking into account some acoustic protections in the digital model of simulation.

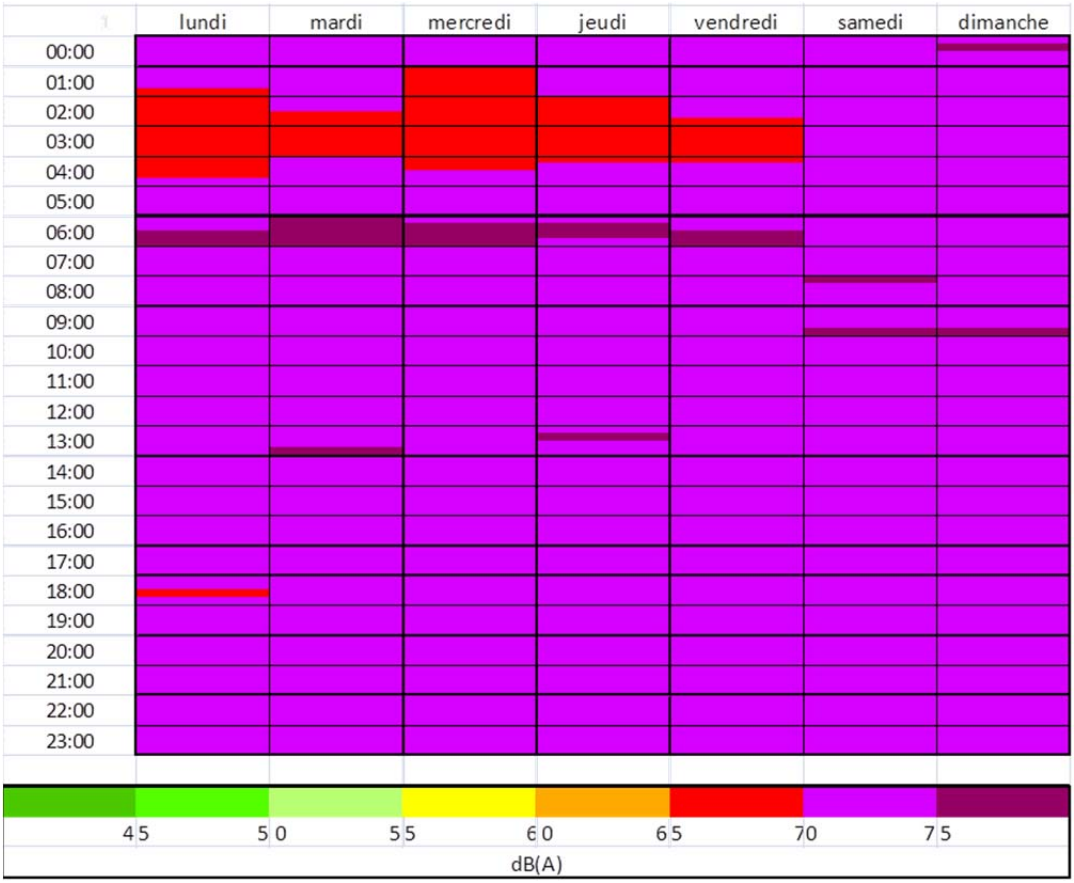
II.3 Highly pervasive noise

The sound of road traffic for people dwelling along the ring road is very pervasive. Measurements have shown high values as early as 5 in the morning and until midnight. During the night, the noise decreases slightly but remains nonetheless high. The levels recorded between 2 am and 4 am are thus only reduced by 6 dB(A) on average compared to the noisiest period (between 6 and 7 am) (cf. graph below)



Hourly variations of noise levels from the daily average.
Variations from the average daily noise level. Week days (outside school holidays)

There are few variations in relation to the day of the week - night levels can even be higher during the week-end (cf. table below)



Variations of the sound levels (by 15 minutes steps) during the week on the site between Porte de Bagnolet and Porte des Lilas.

The conclusion is that for residents whose facades are exposed to the ring road, there is no break, neither at night nor at the week-end , nor even during the school holidays (during which the average decrease recorded was only 1 dB(A)).

II. 4. The impact of noise control devices

A reassuring element is that the study demonstrates the efficiency of noise screens set up along the ring road. On average, indeed, the screens offer a gain of about 7 dB(A). Such a gain is lesser than in theory (cf. graphs below), but nevertheless quite significant when one knows that a decrease of 10 dB(A) corresponds to dividing by half the hearing sensation (the noise is felt to be twice lower). This decrease of noise levels allows in some cases a respect of regulatory limit values. This result should however be qualified, as noise control devices are mainly efficient for lodgings on the lowest floors of buildings.

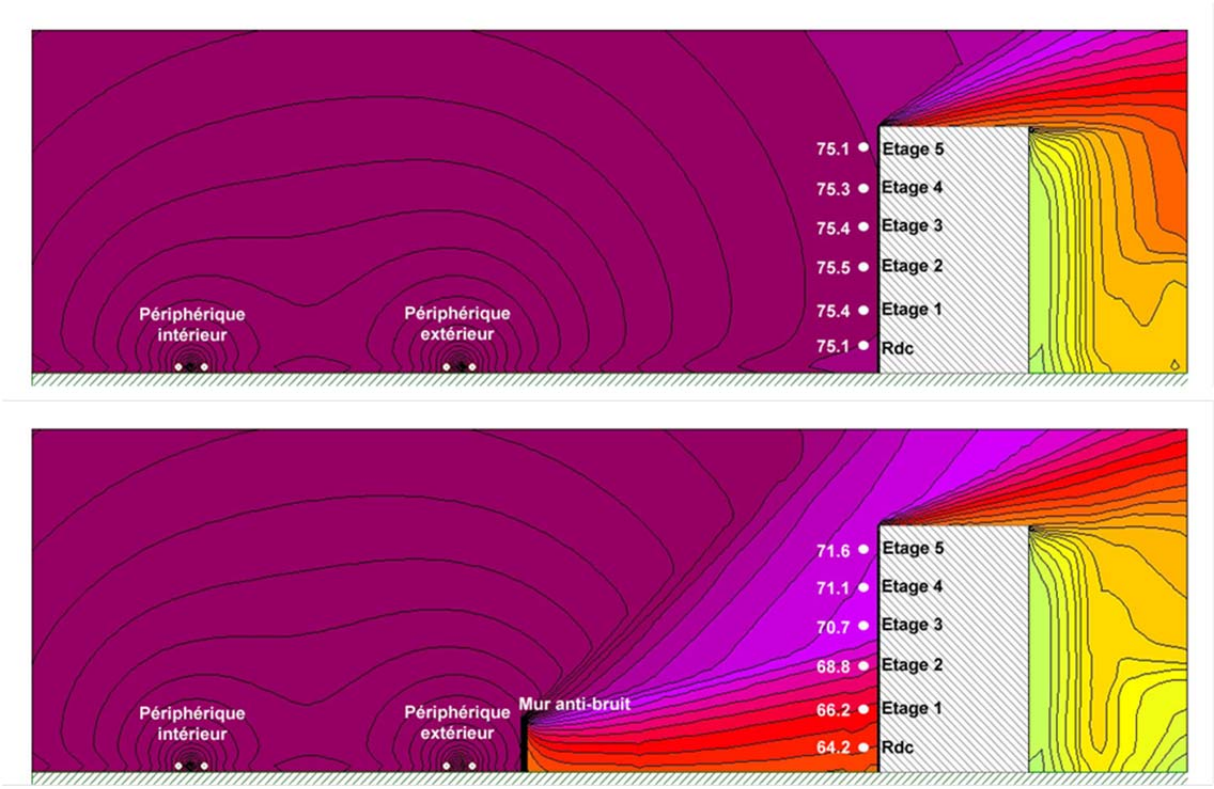


Illustration of the theoretical decrease of noise levels on the façade of a building after setting up an anti-noise wall.

II. 5 Better knowledge on the relationship between noise and traffic conditions

As a first approximation, with all other parameters remaining constant (traffic conditions, vehicles in use, site configuration), the level of noise near transport infrastructure varies according to the flow Q (u/h) and speed V (km/h) of vehicles within this formula:

$$\Delta Lp = 10 \log(Q / Qref) + 20 \log(V / Vref)$$

if V ≥ 50 km/h (source : NFS norm 31-085)

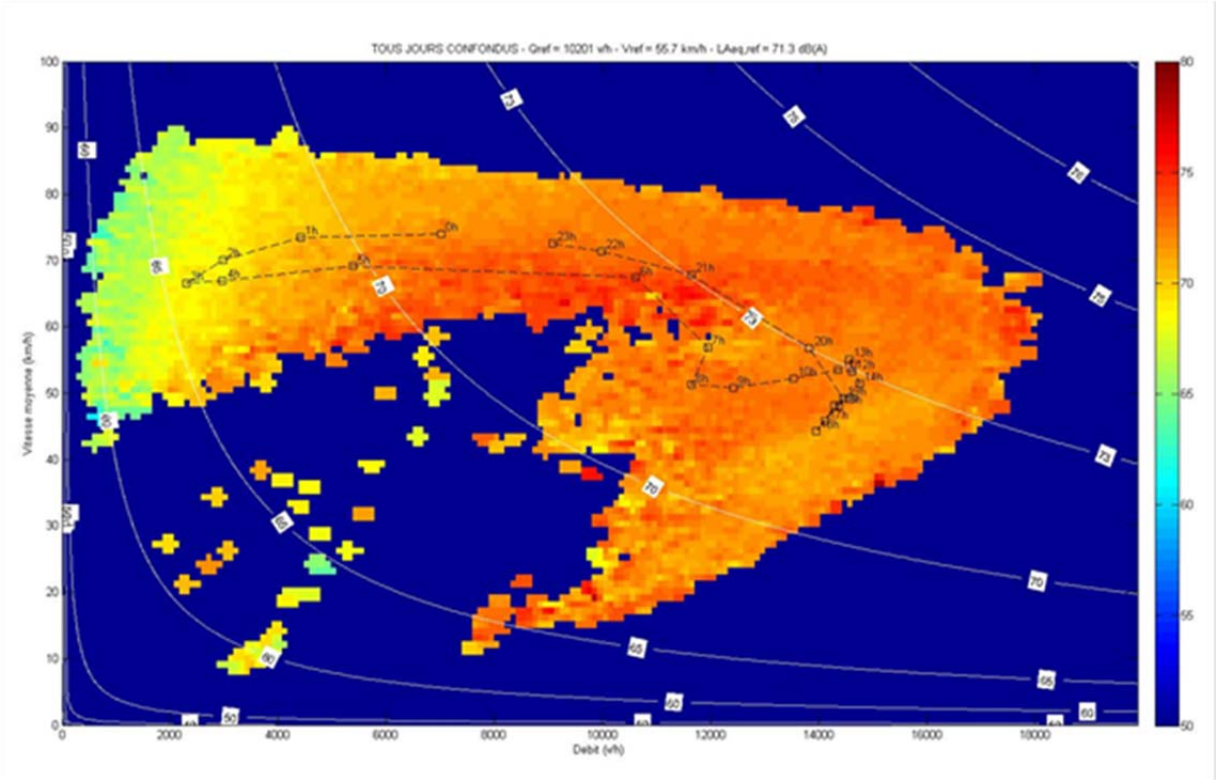
At constant speed, a doubling of the flow thus theoretically causes a 3 dB(A) increase of the noise level. At constant flow, dividing the speed by 2 reduces noise by about 6 dB(A).

The measurement campaign has allowed us to document and to understand in detail the relationships between noise and traffic conditions and notably to highlight the importance of the influence of traffic speed.

Thus, this analysis brings to light the fact that the noisiest situations correspond to traffic configurations offering simultaneously important flows and high speed and that noise tends to decrease in situations of saturation (which is in accordance with theory).

Besides, the analysis shows that the period between 5 and 7 in the morning is particularly noisy. This is partly due to the high speed of vehicles at such a time and also probably to a higher proportion of lorries and freight vehicles within this time span compared with the rest of the day.

The following figure thus allows us to understand the hourly noise levels observed at the station located at the Porte of St Mandé according to traffic conditions. This three-dimensional representation allows us to visualize the whole set of traffic conditions observed during the month of measurement and the associated noise levels.



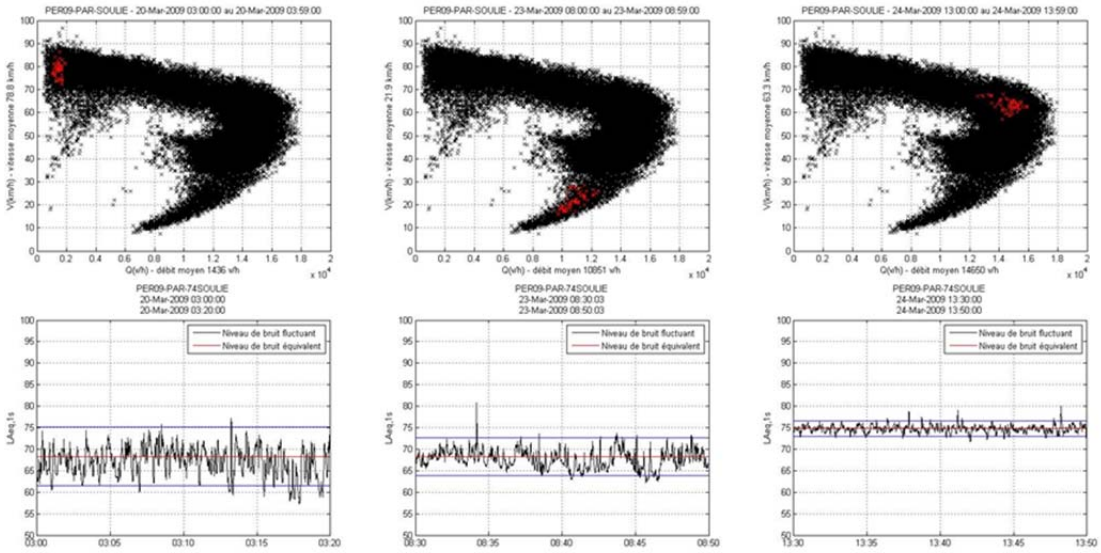
Simultaneous view flow/speed/ noise levels (all days) for the site of measurement at Porte de Saint Mandé.

The graphs below allow illustrating the noise levels generated by the three most common traffic situations occurring on the ring road:

- free-flowing traffic in the middle of the night: little vehicle traffic (around 1500 vehicles per hour) but high average speed (78 km/h: very close to the speed limit)
- saturated traffic during morning peak hours : high traffic (11,000 vehicles per hour) and low average speed due to the congestion (around 22 km/h)
- -dense and fluid traffic conditions in the middle of the day : high traffic (14 000 vehicles/hour) and relatively high average speed (around 63 km/h due to relatively fluid traffic conditions)

These graphs were produced on the basis of results made on the site located on the site between Porte de Bagnolet and Porte des Lilas.

Comparison of noise levels and traffic conditions for three common situations observed on the ring road



Low and fluid traffic middle of the night Noise level: 68.3 dB(A)

Saturated traffic peak hours Noise level: 68.2 dB(A)

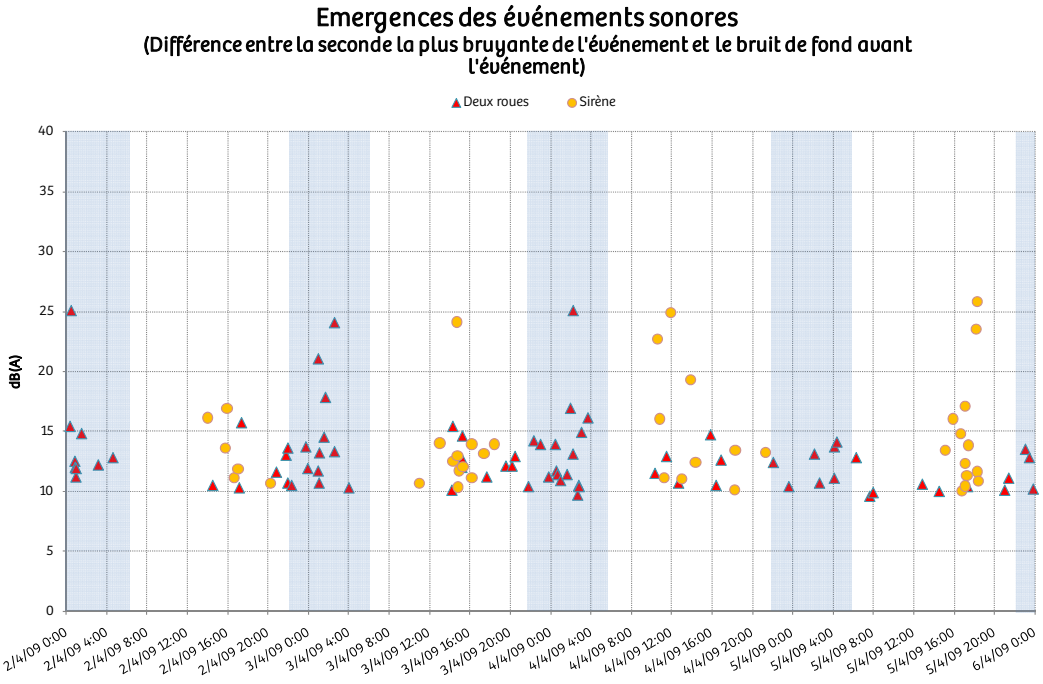
Dense and fluid traffic midday Noise level: 74.8 dB(A)

The average noise level observed in conditions of dense and free-flowing traffic at the beginning of the afternoon exceeds by about 6.5 dB(A) the levels observed for the other two periods. At peak hours, in conditions of saturated traffic, the average noise is almost equal to the level measured in the least noisy situation in the middle of the night while the number of vehicles is nearly eight times higher. The noise reduction caused by a lesser use of the ring road is compensated by an increase of the noise level due to the increase of speed.

The noise environment also varies a lot according to the layout of the site and the traffic conditions. On some sites, the noise near the ring road is relatively continuous; on others, it is more pulsated. This pulsated aspect translates into a perception of isolated passages of vehicles. The presence of more or less frequented parallel pathways, feeder roads or service lanes, the distance from the various noise sources, the traffic conditions according to the time of the day are as many elements which explain this phenomenon.

The study has allowed us to qualify and quantify precisely the events which exceed significantly (by over 10 dB(A) the background noise of traffic -already quite high). According to the configurations observed around the eight fixed stations, between 100 and 1600 emerging events were recorded daily. Such emergences can be related to the passage of particularly noisy vehicles on the ring road, and also to the passage of isolated vehicles on the service lanes between the ring road and the first line of inhabited buildings. Important emergences reaching up to 25 dB(A) have been observed in the middle of the night (cf. figure below). These are mainly related to the passage of two-wheeled vehicles, which are either particularly noisy or driving at an excessive speed. The intensity of such events and their occurrence at night turn them into an important source of nuisance and sleep disorders for residents. As for sirens, they were mainly identified during the day or in the evening when traffic is dense or saturated.

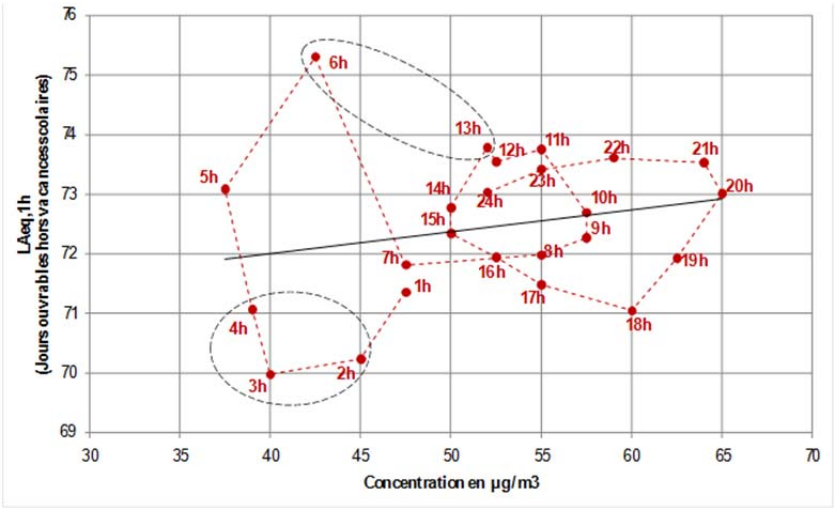
Emergence of noise events
(difference between the noisiest second of the event and the background noise before the event)
Δ Two-wheels O Sirens



Noise emergences generated by some peak noises
Observations made at the Bagnolet cemetery adjacent to the ring road, Paris 17th arrondissement

II. 6. No necessary time correlation between noise and air pollution

On the occasion of this campaign, Bruitparif teams have been able to compare measurement data with data collected by Airparif during previous studies for two sites. The results show that though road traffic is the main cause of both pollutions, there is no time correlation between the two nuisances. Indeed, air quality is most affected during peak hours (for particles and azote oxides) while noise levels tend to be higher when there is less traffic but a higher speed (as is the case during the time slots from 6 to 7, 11 to 12 and 20 to 23). The noisiest hours thus do not necessarily correspond to traffic peak hours, nor to hours of heaviest air pollution.



Couples: hourly concentration in azote dioxide/noise levels at the level of the Porte de Bagnolet

II.7 Recommendations

All these elements have allowed us to issue a number of recommendations to the main actors to fight even more efficiently against the noise nuisances generated by the ring road.

Besides the multiplication of noise protections and the improvement of the façade isolation of buildings adjacent to the ring road, other means can be considered, notably by diminishing noise at its source.

To ensure the peace of residents, the priority is to decrease night noise. This could be done by reducing the speed limit or by encouraging drivers not to exceed 50 km/h at night. Special care should be devoted to the period between 5 and 7 in the morning, when noise levels are particularly high. It would be interesting to make a further study coupling noise measurement and traffic composition over this period so as to better understand the contribution of freight vehicles and lorries in the noise levels observed.

The implementation of the latest generation of low-noise asphalts would allow to gain a few decibels, especially when traffic speed is relatively high (a theoretical gain of 5 dB(A) for a speed of 70 km/h)

During new planning operations or the renovation of some areas, special attention should be devoted not to increase the number of lodgings exposed to the noise of the ring road, by favouring the setting up of buildings for commercial or work purposes in the first line , which can work as screens for the lodgings on the second line.

Prevention and awareness-raising actions should also be reinforced in order to promote less noisy behaviour on the ring road. To that effect, setting up signs displaying noise levels and prevention messages might be a relevant solution to experiment. Engaging the users of the ring road, especially two-wheeled motor vehicle drivers - particularly noisy or driving at excessive speed, which is one of the main causes of noise peaks during the night-, could be an interesting target.

III. Further studies made by BruitParif in 2010 and 2011

In the wake of the study carried out in 2009, and so as to bring to light complementary elements within the framework of the elaboration of the Plans of Prevention of Noise in the Environment of Paris, but also of adjacent towns, BruitParif has quantified the population exposed to noise above the limit values along the ring road and has studied the potential impact of some solutions that could be considered.

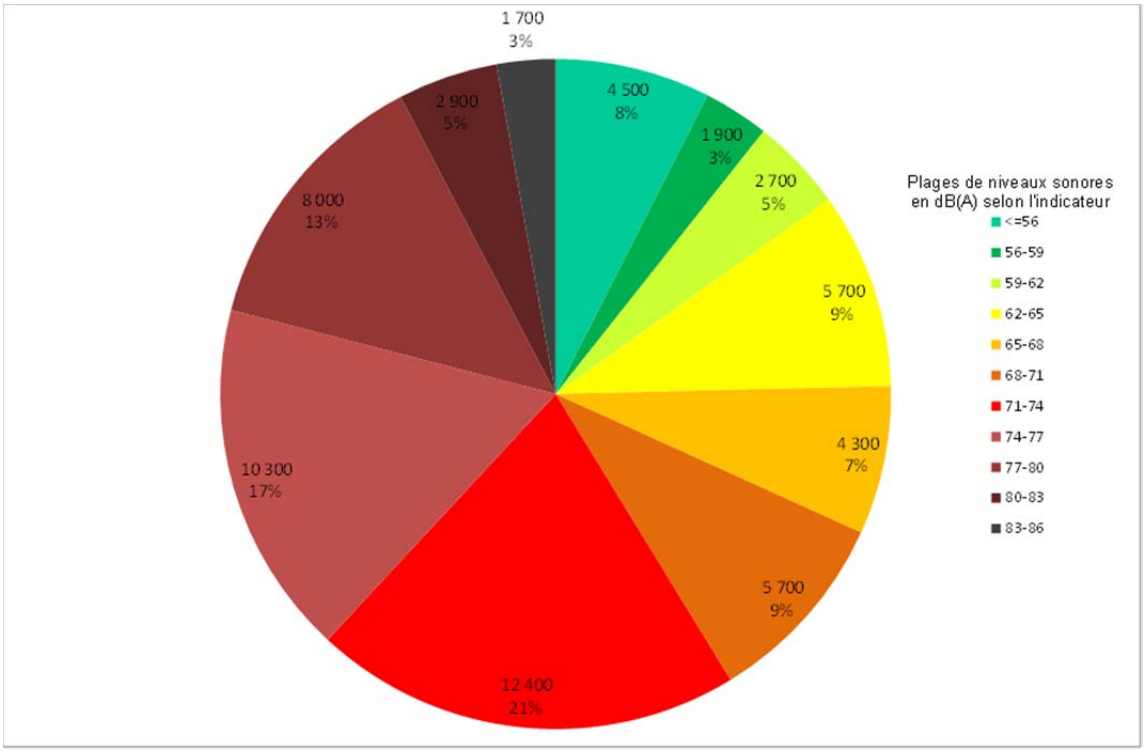
III.1 Estimation of the population exposed to the noise of the ring road.

From the road noise map made by the City of Paris and published on June 30th, 2007 in application of the European directive 2002/CE/49, we have been able to estimate the number of people living near the ring road and potentially exposed to sound levels exceeding the limit values taken by France for traffic noise (68 dB(A) for the Lden indicator and 62 dB(A) for the Ln indicator). To do this, three steps were necessary

1. A selection of the buildings within a buffer zone of 150 m on each side of the ring road which are mainly impacted by the noise generated by the ring road.
2. A selection of exclusively residential buildings and an estimation of the population in these buildings out of the data of the densipop layer given by the I.A.U Ile de France
3. Estimation of the potential level of exposition to noise for the population of each building from the level of the most exposed façade

The results have shown that about 61 000 people are mainly impacted by the noise of the ring road within the 150 m buffer zone on each side of the ring road. Among them, 41000 people (68%) might be potentially

exposed to levels which exceed the limit value of noise relative to the weighted average daily indicator (Lden > 68 dB(A)).



Repartition of residents along the ring road according to their exposition to the noise generated by the ring road (Lden indicator)

37 300 residents of the ring road are likely to suffer from nightly noise nuisance beyond the corresponding limit value (Ln > 62 dB(A))

One notices too that the levels of exposition to noise can be much above the limit values: they can indeed reach values exceeding up to 15 dB(A) the limit values. It should be noticed that over 5000 people are potentially exposed to noise levels exceeding by at least 10 dB(A) the limit values of Lden and Ln (that is to say, noise levels perceived by the human ear as being at least twice higher than the levels corresponding to limit values)

The table below gives the distribution of the populations in a situation of excessive exposition to the noise generated by the ring road according to their department of residence. Thus, 61 % of people live in the Paris area, 22 % in the Hauts de Seine, 10% in the Val de Marne, and 7% in Seine Saint Denis.

	Lden	**Ln**
Département	>68	>62
75	25 100	22 700
93	2 800	2 400
94	4 200	3 700
92	8 900	8 500
Total	41 000	37 300

Count of the populations potentially exposed to noise levels generated by the ring road and exceeding the limit values.

III. 2 Estimation of the potential impact of actions in terms of exposed people

Bruit Parif has been able to quantify the potential impact of actions that could be considered in order to decrease the noise levels on the ring road in terms of a decrease of the number of people exposed beyond limit values. The graphs of page 18 present the results of these partial estimations.

In order to ensure the peace of the residents along the ring road, the priority should be to counter nightly noise. To that effect, the decrease of the legal speed limit from 80 km/h to 50 km/h would be likely to reduce the real traffic speed by 20 to 25 km/h , which would theoretically translate into a decrease by about 3 dB(A) of the night noise levels. This measure would allow decreasing by about 26% the number of people exposed to night noise levels exceeding the limit value. On the other hand, this measure would only allow diminishing by about 4 % the number of people exposed to day noise levels exceeding the limit value for the Lden indicator.

Other complementary actions must thus be considered to diminish noise at its source.

It could be done first by opting for pavement material offering better sound characteristics than the ones currently used on the ring road. For speed limits at around 50 km/h, the gain we can hope for by changing the pavement materials should be within 2 to 3 dB(A) according to the review of knowledge on this topic carried out by BruitParif in 2011. Life-scale experiments will nevertheless have to be implemented so as to validate the technical feasibility of the laying and durability of such pavement materials on a road as frequented as the ring road, as well as the real acoustic gains obtained. The advantage of this type of solution is that the benefit will hold permanently, by day as well as by night. Thus, if such an action was cumulated with a lowering of the speed limit at night, the number of people in a situation of excess of the limit value at night would decrease by about 56 % (between -53 and -59 %) compared to the current situation. As regards the number of people in a situation of excess of the limit value relative to the Lden indicator, the decrease would rather be by around 26 % (between -22 and -30 per cent)

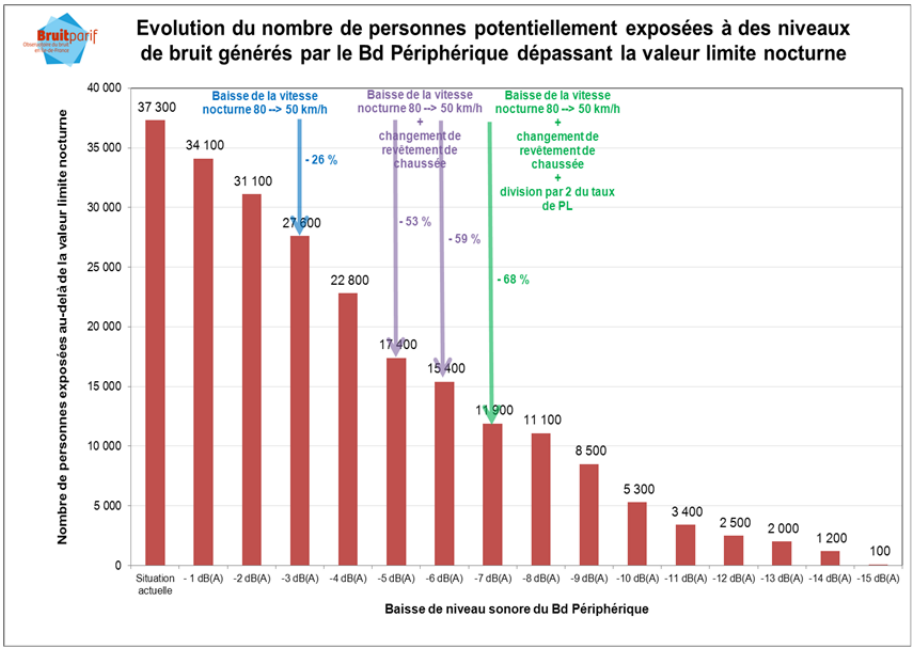
Another way to significantly decrease noise at its source would be to diminish the proportion of lorries. It must be noticed that the average lorry is equivalent from an acoustic point of view to around 7 individual vehicles at a speed of 80 km/h speed and to 10 individual vehicles at a speed of 50 km/h. Dividing by half the number of lorries and freight vehicles circulating on the ring road would theoretically translate into a decrease of noise by 1,5 dB(A) on average, up to 2 dB(A) for the hours at the end of the night when the proportion of lorries and freight vehicles seems to be particularly high. If such a measure was added to the two previous ones (decrease of speed at night and changing the pavement material), the number of people above the limit value would diminish by about 68 % (around two thirds) compared to the current situation. As regards the number of people over the limit value of the Lden indicator, the decrease would stand at around 44 %.

Limiting the peaks of noise generated at night by particularly noisy two-wheeled vehicles and the abusive use of sirens and horns should also be undertaken. These peaks of noise, with punctual emergences up to 25 dB(A) at night weigh little in the calculation of the noise indicators (Ln or Lden) which represent a noise average over large periods. They are nevertheless highly problematic for quality of sleep because they can cause awakenings, whether conscious or not, for residents near the ring road. In order to fight such uncivil behaviour, actions of awareness-raising and repression should be reinforced.

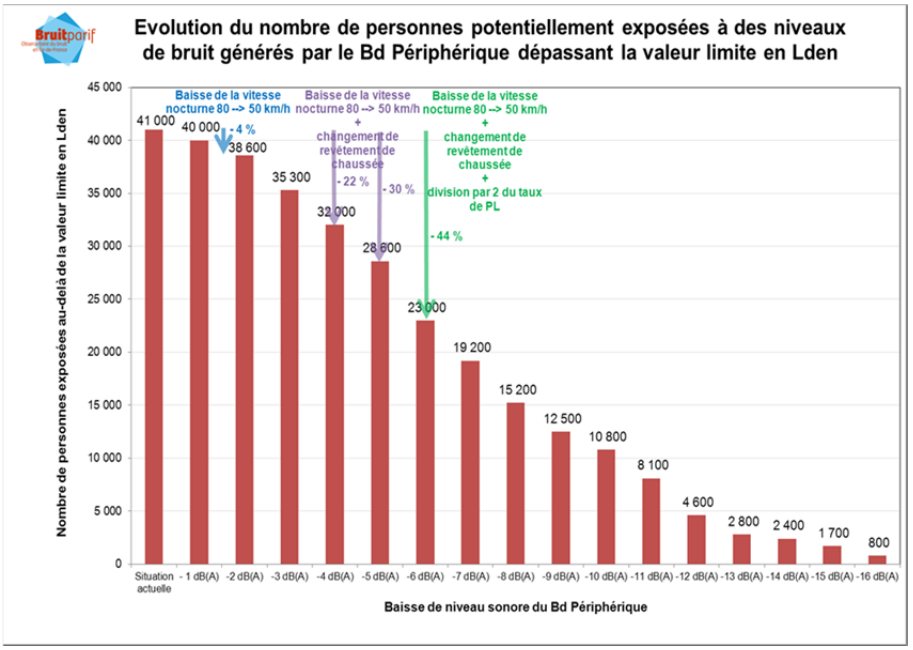
For the 11100 people living in lodgings exposed to noise levels over 70 dB(A), that is to say more than 8 dB(A) over the night limit value, localized complementary actions should be considered at the foot of some buildings, like building anti-noise screens when technically feasible. Such measures indeed allow a decrease of noise levels on the façade of lodgings by about 7 dB(A), at least for lower floors. Solutions of modification of outside facades, by setting up sloping balconies for example, can also usefully be

implemented as they allow reducing noise levels at the level of the windows of the flats. Such solutions can be very efficient for higher floors, as was testified by alterations made on a building in Asnières along the quays, which allowed to diminish by 6,5 dB(A) the noise on higher floors. (Source: Conseil général des Hauts de Seine).

Finally, from a more general point of view, phonic isolation on the facades of buildings impacted by the ring road should be encouraged, and it should be coupled with thermic isolation when the latter is programmed, so as to allow greater comfort inside the lodgings.



Evolution of the number of people potentially exposed to noise levels generated by the ring road over the night limit value Blue: Lowering the speed limit at night from 80 to 50 km/h. Purple: changing the pavement material. Green: dividing by 2 the number of lorries



Estimation of the impact of actions against noise in terms of diminution of the number of people exposed over the limit values (Ln indicator at the top, Lden indicator at the bottom)

These further studies led by BruitParif in 2010 and 2011 have allowed to contribute efficiently to fuelling the thinking within the framework of the working group on the ring road organized by the City of Paris within the framework of the elaboration of its Plan of Prevention against Environmental noise.

IV. Installation of permanent noise measurement stations

So as to monitor the evolution of noise levels generated by the ring road over time, especially in relation with the implemented actions of noise reduction, BruitParif has decided to set up several permanent measurement stations.

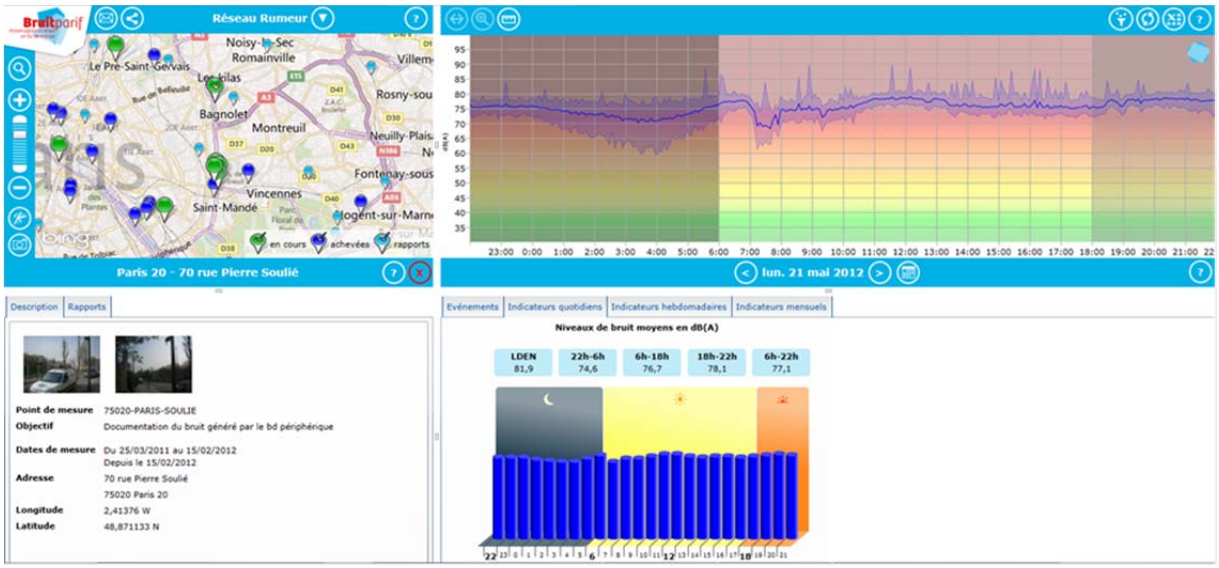
The first one was set up in March 2011 in a situation of resident exposition in front of the building located at number 10, rue Pierre Soulié, in the 20th arrondissement, on the outer side of the ring road. This site had been chosen in the wake of the measurement campaign of 2009, as it was the site where the highest noise levels had been recorded.

A second sector has been monitored since the beginning of May 2012 between Porte de Vincennes and the Lagny bridge. Five stations were set up: one at the level of the central reserve (near the source of cars), and four others on the front of buildings adjacent to the ring road. This sector was chosen to be thoroughly documented as regards noise levels because the City of Paris made it the site of a great project of urban renewal (GPRU) and of pilot measures to fight against noise (experiment of a new anti-noise pavement surface since the end of June 2012). The data recorded by the measurement stations of BruitParif should highlight the impact of the various measures and of the layout implemented in terms of improvement of the sound environment of residents.

Finally, a measurement station was set up at the level of the Porte d'Auteuil on the central reserve and close to the air quality measurement station of Airparif. This station will be in use by mid- October and will allow to finely document the relationships existing between traffic conditions, levels of pollutants, and noise levels and to bring to the light the combined impact of the expected evolutions in terms of traffic conditions (lowering traffic speed, change in the composition of the vehicles fleet) on these two environmental issues.

Location of the permanent stations of noise measurement on the ring road (on the left: rue Pierre Soulié, in the middle: Porte de Vincennes, on the right: Porte d'Auteuil)

The data of these measurement stations can be accessed in real time on the platform displaying the results of the measurement network of BruitParif, the site rumeur, which can be accessed on the Internet at the URL http://rumeur.bruitparif.fr or via the homepage of the Bruitparif website (www.bruitparif.fr , then site rumeur)



V. To go further

The more detailed results of the surveys carried out by Bruitparif on the issue of the noise of the ring road, and more generally the results of actions against the noise of road traffic can be downloaded from the website of BruitParif in the "resources" space

Bruitparif surveys:

Campaign of measurement of noise around the Paris ring road –January 2010

Fighting traffic noise: examples of possible actions – April 2011

Paris ring road: complementary survey – April 2011

Pedagogical and technical file: "Assessment of noise performance of pavement surfaces –december 2011

Bruitparif events /Symposium proceedings

Symposium, 21st September 2011: solutions to diminish road traffic noise – December 2011