forum acusticum 2023

COST-BENEFIT ANALYSIS OF USING LOW NOISE PAVEMENTS IN URBAN AREAS

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ABSTRACT

Despite the presence of noise barriers, many residents living near heavily trafficked roads experience a very degraded sound environment day and night, with significant health and economic consequences (annoyance, sleep disturbance, risk of cardiovascular disease, loss of productivity and property depreciation). Reducing the noise to which these residents are exposed is therefore a key issue.
In the Île-de-France region, some major roads have been equipped with low noise pavements. It is now interesting to study the interest of this type of solution in city centers with speeds below 50 km/h. The European LIFE project "Cool & Low Noise Asphalt" is testing innovative asphalt pavement formulas to fight noise pollution and global warming in Parisian sites with high road noise exposure. Asphalt mixes combine acoustic, thermal, mechanical properties and durability. The health and social benefits of using low noise pavements are generally greater than the costs of the necessary investments. A cost-benefit analysis of these concrete measures to fight noise carried out in Île-de-France region, based on significant examples (A6 motorway and Paris city center), allow to highlight the relevance of initiating these actions of improvement to the sound environment. This article presents these assessments.

Keywords: *low noise pavements, health, socio-economic benefit.*

1. INTRODUCTION

As in Paris, in Europe, urban roads are generally limited to 50 km/h and are punctuated by traffic lights and traffic congestion. The average speeds observed on these roads are low (15 to 20 km/h) but this conceals contrasting traffic regimes with phases of traffic almost at a standstill due to congestion and traffic lights and phases of traffic with instantaneous speeds that can approach the authorized speed limit. Several studies, including one published by Eurocities [1], have shown that for instantaneous speeds between 30 and 50 km/h, which is frequently the case in urban areas, the noise from the rolling of tires on the road surface can exceed that of the engine.
Faced with these considerable economic and social repercussions, it is now necessary for European cities to act on the adaptation of urban road equipment. The significant improvement in the acoustic performance of vehicles, the proactive policies of European cities to exclude the noisiest vehicles, to restrict traffic in dense areas and to encourage electric motorization, therefore legitimize the approach of working on surfaces with soundproofing properties that reduce rolling noise even at urban speeds.
In Île-de-France region, studies conducted by Bruitparif, based on methods proposed by the World Health Organization (WHO) [2], have shown that lowering noise exposure levels by a few decibels can have significant repercussions in terms of improved quality of life and reduced health impacts, which can be quantified from a monetary point of view. The estimate produced in 2021 results in a figure of 42.6 billion euros per year attributable to noise pollution in Île-de-France region [3]. This study has made it possible to put a cost on the years of healthy life lost due to transport noise and to propose monetary estimates for the other impacts of noise: property depreciation, loss of productivity, economic consequences of learning disabilities, impacts of neighborhood noise, noise at work or at school.
In addition to the discomfort felt by the population, this problem can be the cause of significant health effects, particularly at night due to disturbances in the quality of sleep, or repercussions on the cardiovascular system. The WHO considers that noise is the second environmental parameter, after air pollution, that has a health impact on city dwellers.

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The installation of acoustic coatings on roads and highways in the Ile-de-France region has led to significant improvements in the noise situation. Bruitparif has been able to highlight the interest of this type of action by calculating the ratio between the benefits brought to local populations in terms of negative externalities avoided and the cost of the necessary investment.
This article presents the results of evaluations carried out on two projects in the Île-de-France region, on a section of the A6 motorway running through the town of Chevilly-Larue and on three streets in the city center of Paris.

2. A6 MOTORWAY

The A6 motorway is a very important road transport for transit between Paris and the south of the Île- de-France region. Between the municipality of Chevilly-Larue and Paris, it is made up of two interlocking roads, the A6A and A6B, which generate an average of 250,000 vehicles per day. On certain sections, as is the case for L'Haÿ-les-Roses, 12 to 14 lanes of traffic (with the access ramps) cross the urban fabric, making this A6A/A6B the widest motorway in Europe.
Despite the presence of noise barriers, many local residents experience a very degraded noise environment both day and night, with significant consequences for health (annoyance, sleep disturbance, long-term risk of cardiovascular disease) and also for the economy (loss of productivity and property depreciation in particular). Reducing the noise to which the people living along this route are exposed is therefore a key issue.
For this reason, as part of the partnership between the State and the Île-de-France Region to change the road through innovation and experimentation, in October 2017 the services of the Île-de-France Road Directorate (DRIEAT/DIRIF) laid a pavement with acoustic absorption properties on the 1.3 km section of the A6 motorway that runs through the municipality of L'Haÿ-les-Roses.

2.1 Noise monitoring

Since then, Bruitparif has been carrying out long-term monitoring of the acoustic benefits of this pavement using two permanent measuring stations located on the A6 motorway, one in each direction of traffic (cf. figure 1). This monitoring has shown1 a very significant reduction in noise of about 8 dB(A) in the first year after the pavement was laid, and then a gradual deterioration in its acoustic performance over time, which can be estimated at about 1 dB(A) per year, based on the first four years of observation [4]. It can thus be estimated that within nine years, i.e., by 2026, the pavement will probably have lost its sound absorption qualities, and that noise will return to its initial level before the pavement was laid, thus necessitating the renewal of the pavement.

Figure 1 Permanent noise measurement stations installed by Bruitparif since early September 2017 on the A6 motorway at L'Haÿ-les-Roses.

2.2 Exposure of local populations

A map of the noise generated by the A6 motorway in the municipality of L'Haÿ-les-Roses has been produced by Bruitparif for the initial situation before the installation of the noise reducing pavement. This mapping was adjusted and validated using the results of the measurement campaign carried out by Bruitparif in 2017 along the A6 motorway in the situation of the nearest residents [5].
This mapping made it possible to estimate the number of inhabitants of L'Haÿ-les-Roses who were potentially exposed at the front of their homes to noise levels generated by the A6 motorway that exceeded the reference values established for road noise. According to this count, around 8200 and 9200 people respectively were affected by noise levels that exceeded the recommendations set by the WHO [2] recommendations of 53 dB(A) according to the Lden indicator on the one hand, and 45 dB(A) according to the Ln indicator. In addition, 1,670 and 1,474 people respectively were potentially exposed to noise levels that exceeded the regulatory limit values set by France, of 68 dB(A) according to the Lden indicator on the one hand, and 62 dB(A) according to the Ln indicator on the other limit values set by France, of 68 dB(A) according to the Lden

indicator on the one hand, and of 62 dB(A) according to the Ln indicator on the other [6].
Similar modelling, taking into account the reduction in noise caused by the noise reducing pavement and the gradual deterioration in its performance, was carried out for each of the years following the installation of the pavement, until the projected return to the initial situation expected by 2026.
For each of these years, counts of the populations exposed to noise from the A6 were produced using the same methodology as for the initial situation. Thanks to the anti-noise pavement, the number of inhabitants exposed to noise from the A6 motorway was reduced by about half (51%) one year after the pavement was laid, and the number of people potentially exceeding the limit values by 85%. Three years later, these reductions still amount to 41% and 72% respectively.

2.3 Health and economic costs avoided

The methodologies used to calculate the social cost of noise [3, 7] could then be used by Bruitparif to conduct a cost-benefit analysis of this noise abatement measure.

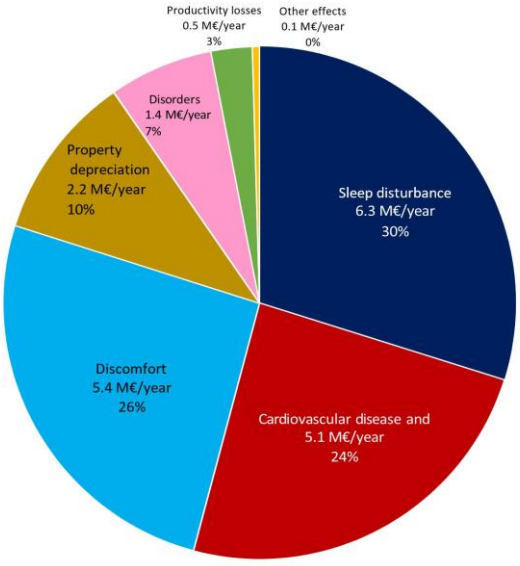

Figure 2 Breakdown of the social cost of noise generated by the A6 motorway in the municipality of L'Haÿ-les-Roses for the situation before the installation of the new pavement.

The aim was to compare the investment of 3.5 million euros, contributed 50% by the State and 50% by the Île-de-France Region, which was necessary to lay the pavement, with the benefits that this measure generated in terms of health and economic costs avoided for the local population, due to the reduction in their exposure to noise.
Before the installation of the anti-noise pavement, the noise from the A6 motorway represented an estimated cost of 21 million euros in total borne each year by the people of the city in the form of deterioration in their health (disturbed sleep, increased risk of developing cardiovascular or metabolic disease, discomfort, anxiety disorders, etc.), property depreciation and loss of productivity at work (cf. figure 2 - breakdown of the cost according to the estimated health and economic effects).

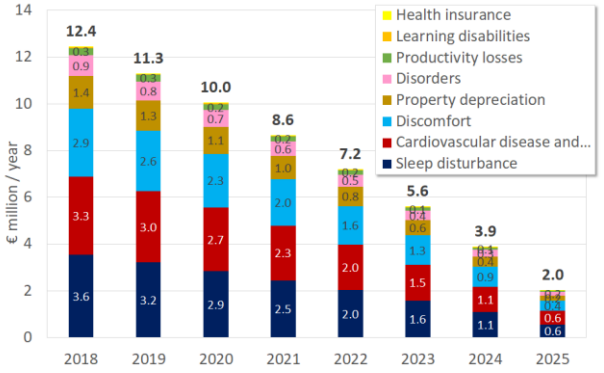

Figure 3 Social noise costs avoided (by type of effect) due to the presence of the new pavement on the A6 motorway at L'Haÿ-les-Roses, according to its progressive loss of acoustic effectiveness over time.

The reductions in noise exposure of inhabitants living near the A6 motorway, recorded following the installation of the noise reducing pavement, were converted into avoided health and economic costs, for each of the eight years from the year following the installation of the pavement (2018) to the forecast year (2026) of its complete loss of acoustic effectiveness (cf. figure 3). €12.4 million, reducing the social cost of noise by 59% (from €21 million to €8.6 million). These benefits will then decrease as the pavement gradually loses its acoustic effectiveness over time. At the end of 2021, more than four years after the implementation of the pavement, the social cost of noise is still reduced by 41%, whereas the expected reduction will probably only be 10% by 2025.

2.4 Benefit / cost ratio

€61 million of negative externalities avoided, which leads to a net benefit of €57.5 million for this noise abatement

measure, for a ratio between the benefits and the amount invested of 17.
This example of a cost-benefit analysis of a concrete noise abatement measure carried out in the Île-de-France region highlights the relevance of undertaking actions to improve the noise environment, as the social benefits provided are generally much higher than the necessary investment costs, This is all the more true since the solutions implemented often have co-benefits with other ecological or social issues (in the case studied here, a co-benefit in terms of road safety due to a more recent pavement surface with fewer deformations than the previous one and therefore safer).

3. CITY CENTER OF PARIS

This chapter presents the first results of the socio-economic evaluation of the LIFE Cool & Low Noise Asphalt project. By designing new pavements with both noise and thermal properties, this project provides new concrete tools for policy making, contributing to a real and sustainable improvement in the well-being of city dwellers.

3.1 LIFE Project: Cool & Low Noise Asphalt

As part of the European LIFE program, the City of Paris, in partnership with Colas, Eurovia and Bruitparif, is testing three innovative pavement surfaces to fight against both noise pollution and global warming [8].

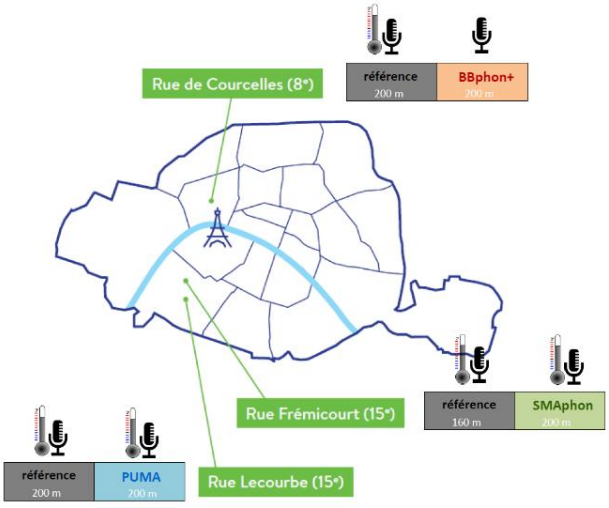

Figure 4 Pilots sites; LIFE Cool & Low Noise Asphalt.

In 2018, three new types of asphalt mix (PUMA, Bbphon+ and SMAphon) gathering both phonic and refreshing properties, while maintening acceptable durability, were developed [9, 10]. From 2018, 1200 meters of roads are surfaced with new asphalts having acoustic, thermal and mechanical properties. These new formulas are tested on three pilot sites, each 400 meters long, in three Parisian sites heavily exposed to road noise: Frémicourt street, Lecourbe street and Courcelles street. Each site is equipped with various sensors and is coated half with an experimental formula and the other half with the Parisian standard pavement (cf. figures 4 and 5).

Figure 5 Frémicourt street with new asphalt mixes, October 2018.

The new types of asphalt mix are tested on road sections of about 200 m and compared to the standard solution deployed by the City of Paris on Parisian roads: ACR 0/10 AC2 and BBMA 0/10. Also, sections of about 200 m of these standard asphalt mix were also laid on the three experimental sites.

3.2 Socio-economic assessment (noise)

The acceptability of these solutions depends in part on the results of the socio-economic evaluation of the solutions tested. The aim is to quantify and monetise the improvement in the quality of life and the state of health of local residents, as well as the improvement in work productivity and the property value of homes that will result from the reduction in noise observed on the experimental sites. This quantification work is based on the methodologies recommended by the WHO to quantify the health impacts of road traffic noise and the associated economic consequences, on those implemented at national level by the firm EY on behalf of the Conseil National du Bruit and ADEME for the other socio-economic impacts of noise, as well as on recent publications on these subjects [7]. The project has many positive repercussions on the local economy and the population: an indirect economic impact linked to the improvement of the quality of life

(reduction of discomfort) and the state of health (improvement of the quality of sleep, reduction of cardiovascular risks, etc.) of the populations living near the roads which will have benefited from the new pavement formulations, in connection with the reduction of noise.

3.3 First results

On the basis of the results observed on the reduction in night-time noise levels linked to the experimentation of the new surfacings [11] (cf. tables 1 and 2), the benefit generated for the Parisian population in terms of health and economic impact can be quantified, in the case of the application of the experimented surfacings to part or all of the Parisian road network. On the basis of these noise reductions taken into consideration over the period 10pm-6am, an evaluation of the annual savings in millions of euros generated by the use of innovative pavement surfacing could be initiated. An initial evaluation taking into account the main economic factors: health (discomfort and sleep disturbance) and economic (loss of productivity) is now available. These costs are compared with the average costs of using and maintaining the innovative solutions compared with conventional pavements. Different scenarios for the deployment of innovative solutions on the Parisian road network are studied within the framework of the LIFE Cool & Low Noise Asphalt project: partial or full deployment.

Figure 6 Acoustic station and thermal station; Frémicourt street 75015 Paris (SMAphon).

If the 50 km/h Parisian road network is treated (cf. figure 7), after 5 years, the replacement of existing pavements with innovative solutions will generate savings of around €90 million. The average cost of laying SMAphon and BBphon+ mixes on the 50 km/h Parisian network is estimated at around €10 million. The cost of PUMA asphalt is approximately €40 million. The investment would be recovered after one year for the asphalt and about two years for the PUMA asphalt.

Table 1. Monitoring of road noise reduction compared to the initial state (22h-6h).

Δ Ln compared to existing in dB(A)	**Year 2018**	**Year 2019**	**Year 2020**	**Year 2021**	**Year 2022**
SMAphon	-3.1	-2.7	-2.1	-2.4	-2.1
BBphon+	-2.3	-1.4	-1.0	-1.4	-1.2
PUMA	-1.1	-1.1	-1.3	-1.4	-1.6
Average	**-2.18**	**-2.04**	**-1.90**	**-1.77**	**-1.63**

Table 2. Monitoring of road noise reduction compared to reference solution (22h-6h).

Δ Ln compared to reference in dB(A)	**Year 2018**	**Year 2019**	**Year 2020**	**Year 2021**	**Year 2022**
SMAphon	-1.3	-1.1	-0.7	-0.6	0.2
BBphon+	-1.4	-1.1	-1.1	-0.5	-0.3
PUMA	-	-	-	-	-
Average	**-1.39**	**-1.06**	**-0.73**	**-0.41**	**-0.08**

Figure 7 50 km/h Paris road network in 2022.

For the entire Paris road network, the savings would be in the order of €1 billion for an investment of between €90 million (SMAphon and BBphon+) and €375 million (PUMA).
If the 50km/h Paris road network is treated, the savings made by innovative mixes (SMAphon and BBphon+) compared with standard mixes (BBM0/10) are of the order of €34 million after 5 years (cf. figure 8). The extra cost would be recovered in the first year. If the entire Paris road network is treated, the savings would be in the order of €400 million (cf. figure 9).

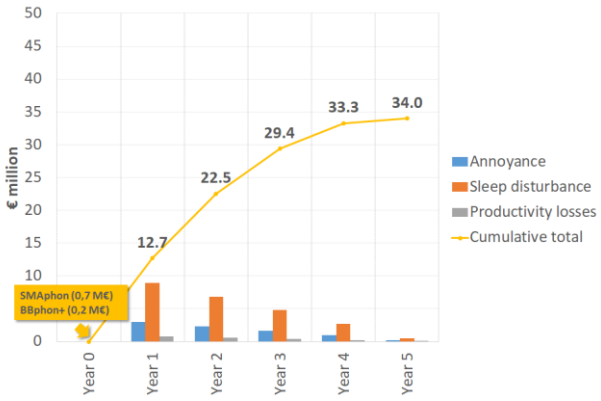

Figure 8 Savings associated with innovative asphalt mixes compared to standard asphalt mixes; 50 km/h Paris road network.

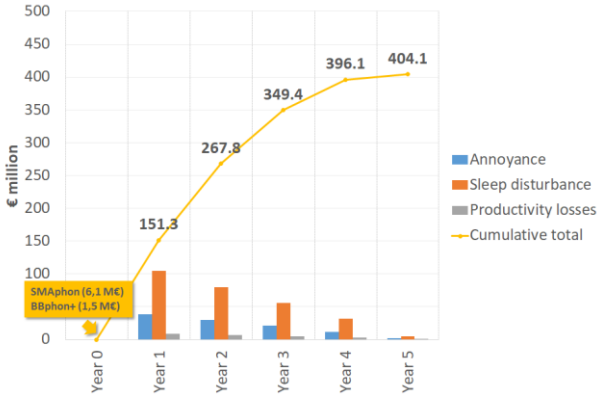

Figure 9 Savings associated with innovative asphalt mixes compared to standard asphalt mixes; entire Paris road network.

3.4 After LIFE Project

Continued monitoring of acoustic performance after the end of the project will provide a socio-economic evaluation over a 10-year period. If the pilot project is successful, the whole of the Parisian road network could eventually benefit from an asphalt mix with acoustic and thermal properties, becoming an example for European local authorities and professionals.

4. CONCLUSION

Bruitparif has applied the methodology used to calculate the social cost of noise in France in order to conduct a cost-benefit analysis of the noise abatement lining measure on two examples in the Île de France region. On the 1.3 km section of the A6 motorway, which crosses the municipality of L'Haÿ-les-Roses, the evaluation results in a total of €61 million in avoided health and economic costs over the 8 years of expected performance of the pavement, for an implementation cost of €3.5 million. The forecasts for the deployment of the innovative pavement surfacings developed as part of the LIFE Cool & Low Noise Asphat project also show a significant difference between the savings generated and the investments made. For a deployment on the entire 1600 km of the Parisian road network, the estimated savings over a period of 5 years would be of the order of €1 billion for an investment up to 10 times lower.
On these two projects, Bruitparif is continuing to monitor acoustic performance. These actions will provide socio-economic evaluations over periods longer than 10 years.

5. ACKNOWLEDGMENTS

The LIFE COOL & LOW NOISE ASPHALT project partners thank the European Commission for its trust and financial support.

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