inter.noise
21-24 AUGUST
SCOTTISH EVENT CAMPUS
GLASGOW 2022

Quantification of the social cost of noise in France and application of the methodology to the Ile-de-France region

Fanny Mietlicki[1], David Bernfeld[2]
Bruitparif
32 boulevard Ornano 93200 Saint-Denis, France, Metropolitan

Emmanuel Thibier[3]
Ademe
500 Rte des Lucioles, 06560 Valbonne, France, Metropolitan

ABSTRACT

The National Agency for Ecological Transition (ADEME) carried out in 2021 a study of the social cost of noise in France that was estimated at 147.1 billion € per year. This cost has been calculated at 97.8 billion € per year for noise generated by transport, at 26.3 billion € per year for neighborhood noise and at 21 billion € per year for occupational noise. Health costs are predominant (86% of total) and correspond mainly to the economic valuation of the burden of disease of noise as a result of its adverse effects (annoyance, sleep disturbance, cardiovascular and metabolic diseases, psychological disorders, learning difficulties, etc.). Secondly, it also includes non-health costs such as loss of productivity and property depreciation.
Bruitparif, the noise observatory for the Ile-de-France region, has applied and adapted the methodology to the data and studies available at the regional scale. This results to 42.6 billion € per year, i.e. 29% of the national total.
These studies provide reference elements for comparing the financial cost of noise prevention and mitigation measures with the social benefits that are likely to result in terms of improved well-being for the population and avoided costs for the community.

1. INTRODUCTION

According to the World Health Organisation (WHO) [1], noise is the second most damaging environmental factor in Europe, after air pollution: around 20% of the European population (i.e. more than 100 million people) is chronically exposed to noise levels that are harmful to human health. Noise, like all pollution, generates negative externalities that are not traded on the market and are therefore not compensated. Thus, it is important to calculate the social cost of these externalities, i.e. to put a monetary value on the impacts generated by noise in order to assess their significance. These externalities are classified into two types of costs: on the one hand, market costs, which relate to tangible expenditures made by society in monetary form, and on the other hand, non-market costs, which are generally non-monetarised and therefore non-tangible, i.e. their value is not directly measured in euros.

[1] fanny.mietlicki@bruitparif.fr
[2] david.bernfeld@bruitparif.fr
[3] emmanuel.thibier@ademe.fr

An initial study [2] carried out in 2016 by EY on behalf of ADEME in collaboration with the Conseil national du bruit (CNB), established the social cost of noise in France at €57.4 billion per year.
A new study [3] has been carried out in 2021 by I CARE & CONSULT and ENERGIES DEMAIN on behalf of ADEME with the collaboration of experts from the Conseil national du bruit (CNB). It has enabled this work to be extended, by updating the figures using the latest scientific publications concerning the impacts of noise, and by extending the scope of the study to new sources of noise (construction, hospitals), new health effects (hypertension, obesity, type 2 diabetes, psychological disorders, hearing loss) and a new cost item (expenditures related to noise control).
Bruitparif then worked on adapting the figures [4] to the scale of the Ile-de-France region, by applying the methodology implemented at the national level to the data available in the Ile-de-France region.

2. METHODOLOGY

Different methodologies were applied depending on the availability of robust literature data or not. A certain number of results were approximated from data and results for another noise source, or were based on assumptions derived from survey results or polls, not necessarily scientific. The assessment takes into account three sources of noise: transport noise, neighbourhood noise and occupational noise. Two types of costs were included in the study: non-market costs, which correspond to the economic valuation of the loss of well-being and healthy life due to the consequences of noise on the health of the exposed populations; and market costs, which are related to productivity losses, property depreciation or health expenses caused by noise.

2.1 Methodology for assessing transport noise costs

The costs of the non-market health effects of transport noise could be estimated using a four-step methodology:

1) Data from the strategic noise maps produced in application of the European directive 2002/49/EC were used to estimate the number of people exposed per 5 dB(A) range, from 45 dB(A) for the Lden indicator, and from 40 dB(A) for the Lnight indicator.
2) Among the population exposed to noise, the number of people affected by each health effect could then be estimated in two different ways, depending on the effect:
   - Either directly from dose-response curves published in the literature which establish an absolute risk depending on the level of exposure (method applied for annoyance [1, 5, 6], sleep disturbance [1] and partly for learning difficulties [7]);
   - Or from increase values of relative risk with increasing noise exposure (method applied for ischaemic heart disease [1], cardiovascular accidents (strokes) [1], hypertension [5] as well as for obesity [8] and diabetes [9]) or from knowledge of the odds ratio (method applied for anxiety and depression [10]).
3) Using a disability weight (DW) factor, defined by the WHO [1, 11, 12] or the OECD [13] and defining the share of a disability adjusted life year (DALY) due to the health effect considered in a year, it is possible to calculate the number of healthy life years lost due to this effect.
4) Finally, the number of years of healthy life lost can be monetised using the €132,000 value for a year of healthy life (reevaluated for the year 2020), as issued by the Quinet Commission [14].

In addition to the years of healthy life lost and premature mortality due to the health effects of transport noise, there are also costs related to the compensation and treatment of induced pathologies. Among these costs were considered the consumption of medication and hospitalisations. The hospitalisation costs were estimated from the number of people affected by cardiovascular disease related

to transport noise, the rate of cardiovascular diseases leading to hospitalisation (source: Swiss Health Observatory) and the average cost of hospitalisation in a cardiology unit (source: SCANsanté).
Besides the effects on human health, the literature shows that transport noise can also have economic consequences, generating productivity losses and property depreciation. The costs of transport noise on productivity have been estimated using the following hypothesis: for active people affected by sleep disturbance, the loss of productivity is about 2.4% [17]. The cost of noise-induced property depreciation was estimated using depreciation functions from the literature [18, 19, 20, 21] that were applied to transactions according to their noise exposure.

2.2 Methodology for assessing the costs of neighbourhood noise

The term neighbourhood noise includes noise generated by private individuals (such as TV/music, gardening, DIY and pet noise, etc.), commercial and leisure activities (such as bars, restaurants, terraces and recreational activities) and construction sites. Unlike transport noise, few studies quantify the consequences of neighbourhood noise on health, behaviour or property value. However, there are population surveys and polls that provide a basis for estimating the proportion of the population affected by the effects of neighbourhood noise [16, 22]. The calculation of the induced cost was then extrapolated from the methodologies used for transport noise, except where specific studies existed [23, 24, 25, 26].

2.3 Methodology for assessing the costs of occupational noise

The occupational environment can also be a source of significant noise pollution due to the machinery and equipment used, interactions between colleagues, students, staff and/or movements...
Four types of occupational noise costs were considered:

- Costs related to hearing loss generated by occupational noise exposure, as health costs that are partly market costs (compensation and treatment of deafness) and partly non-market costs (costs integrated only in the regional study carried out by Bruitparif based on the data published in 2016 concerning the economic impact of hearing loss [27]);
- Costs related to accidents caused by noise at work [28], as market health costs;
- Costs related to the annoyance of workers [29] or students and teachers exposed to noise [30, 31], as non-market health costs;
- Loss of productivity [32] caused by noise at work, as non-health market costs.

2.4 Methodology for assessing expenditures related to combating noise

In addition to the social costs related to the various sources of noise, there are also cross-sectoral costs, i.e. expenditures related to noise prevention, reduction and monitoring. These have been estimated by taking into account the expenses incurred in combating noise as reported by the Ministry of Ecological Transition, which amount to approximately €2 billion per year.

3. RESULTS FOR FRANCE

The total social cost of noise in France is estimated at 147.1 billion euros each year. Two thirds (66.5%) of the costs are transport related (€97,8 bn): road noise represents 54.8% of the costs (€80,6 bn), rail noise 7.6% (€11,1 bn) and air noise 4.1% (€6,1 bn). Neighbourhood noise represents 17.9% (€26,3 bn) of the total costs. A significant part (14.2%) of the costs also comes from occupational

noise (€21 bn). Finally, 1.4% of the costs correspond to expenditures for combating noise. Non-market health costs, amounting to 126.3 billion euros, represent the vast majority of the social cost of noise (86%).

The present study includes three major changes compared to the previous study published in 2016:

1) An improved count of the persons exposed to transport noise due to data from the strategic noise maps published between 2017 and 2020, which are more complete than those used in the 2016 study. This increases the figure from €57.4 billion to €63 billion (+€5.6 bn) on the basis of the 2016 study's scope and estimation methods;
2) An update of the evaluation methods to take account of new knowledge and recommendations, with the same scope of effects and expenditure items as in the 2016 study: (+€39 bn). This update concerns:
   a) The updated dose-response curves for annoyance, sleep disturbance and ischaemic cardiovascular disease resulted in an increase in the social cost of noise of +€6.8 bn, at the same scope of effects as the 2016 study.
   b) Changes in some estimation parameters: change in the statistical value of a year of healthy life used to evaluate welfare losses and review of the assumptions made for some costs (mainly productivity losses and property depreciation); impact: + €32.2 bn.
3) An expansion of the scope of the study (+€45.1 bn) with the inclusion of :
   a) New health effects: obesity, cardiovascular diseases, mental health, diabetes; impact: +€37.7 bn.
   b) New sources of noise exposure: construction sites and hospitals; impact: +€5.3 bn.
   c) New expenditure item: combating noise; impact: +€2 bn.

In total, these changes lead to an increase of 89.7 billion euros compared to the 2016 study, i.e. a 156% revaluation of the total cost. This reevaluation is explained by 6.2% by the improvement of the population count, 43.5% by the update of the evaluation methods and 50.3% by the extension of the study perimeter.

4. RESULTS FOR ÎLE-DE-FRANCE

The work carried out by Bruitparif has made it possible to quantify the costs at the Île-de-France regional level: the result obtained, 42.6 billion euros per year, represents 29% of the costing carried out at national level.

4.1 Transport noise

The assessment carried out establishes that the costs caused by transport noise in Île-de-France represent €26 billion per year, i.e. 62% of the regional costing.

The associated costs correspond, for 86% of them, i.e. €22.5 billion/year, to the economic valuation of the 158,000 years of healthy life lost each year as a result of sleep disturbance, discomfort, cardiovascular disease, obesity, anxiety disorders, type 2 diabetes and learning difficulties induced by transport noise, as well as the 496 premature deaths due to ischaemic heart disease induced by road noise. The remaining part (€3.5 billion/year or 14%) corresponds to the costs of property depreciation (€2.7 billion/year), productivity losses (€0.75 billion/year) and the costs of medication and hospitalisation associated with transport noise-related diseases (€50 million/year).

The cost associated with road noise amounts to €18.1 billion/year, i.e. 43% of the regional total, the cost of aircraft to €4.1 billion/year, i.e. 10% of the regional total cost, and the cost of rail noise to €3.8 billion/year, i.e. 9% of the regional cost.

4.2 Neighbourhood noise

Reaching €10.4 billion/year, neighbourhood noise represents 24% of the regional total cost, broken down into €6.4 billion/year (i.e. 15% of the total) for individuals' noise, €2.4 billion/year (i.e. 5% of the total) for construction sites and €1.6 billion/year (i.e. 4% of the total) for noise generated by professional or recreational activities in the neighbourhood.

4.3 Occupational noise

With a cost of €5.3 billion/year, i.e. 12% of the regional cost, exposure to noise at work (€3.9 billion/year, i.e. 9% of the total) or at school (€1.4 billion/year, i.e. 3%) also appears to be a major issue in Île-de-France. The consequences of exposure to noise at work or at school include annoyance, fatigue, hearing loss and learning difficulties for €3.4 billion/year, loss of productivity (reduced performance and concentration) which represents a very high cost for companies (€1.8 billion/year). The cost of compensation for occupational deafness and noise-related accidents (due to masking of warning signals or diversion of attention) is estimated at €0.1 billion/year.

4.4 Cross-sectoral expenditure

Finally, 1.9% of costs (€0.8 billion/year) correspond to expenditures to treat and prevent noise.

4.5 Contribution of the various effects

The social cost of noise in the Île-de-France region is 84%, i.e. €35.8 bn/year, due to the consequences of noise on human health, mainly due to non-market costs (€35.6 bn/year) linked to the economic value of the 254,000 years of healthy life lost each year, as a result of the population's exposure to noise. The health effects with the highest costs are, in decreasing order:

- Noise-related sleep disturbance, which directly affects 1.4 million people in Ile-de-France (12% of the regional population), represents a cost of €13.1 bn/year, or 31% of the total.
- The high level of annoyance linked to noise concerns nearly 4.5 million inhabitants (37% of the regional population) and represents a cost of € 11.8 bn/year, i.e. 28% of the total.
- Cardiovascular diseases (ischemic diseases, myocardial infarction, strokes, hypertension) attributable to noise represent € 3.5 bn/year, i.e. 8% of the total, and affect about 83,000 people.
- Psychological disorders caused by exposure to noise concern nearly 169,000 people at a cost of €3.2 bn/year, i.e. 7% of the total.
- Noise-related obesity affects nearly 234,600 people (1.9% of the population) at a cost of €3.1 bn/year, or 7% of the total.
- The deterioration of good health associated with hearing loss caused by noise at work would represent a cost of €0.5 bn/year, or 1.2% of the total.
- Noise-induced learning difficulties would affect more than 361,000 young people at school for a cost of €0.3 bn/year, or 0.7% of the total.
- Expenditure incurred by the public health insurance system as a result of drug consumption, occupational deafness, work-related accidents and hospitalisations linked to noise-induced pathologies represent an amount of €0.2 bn/year, i.e. 0.4% of the total.
- Finally, type 2 diabetes for €0.1 bn/year, i.e. 0.2% of the total. It should be pointed out that studies on the links between noise exposure and type 2 diabetes are still few and far between, and that this estimate should therefore be considered as fragile.

The other types of costs, which represent €6.8 bn/year, or 16% of the total cost, are non-health market costs related to:

- The depreciation of property exposed to noise for an amount of €3.1 bn/year representing 7% of the total.
- Loss of productivity at work due to noise (reduced concentration and efficiency), which represents the equivalent of 57,500 full-time equivalents lost each year and an amount of €2.9 bn/year, i.e. 7% of the total cost.
- And finally, cross-cutting expenditure on noise prevention for €0.8 bn/year, or 1.9% of the total.

4.6 Importance of the Île-de-France region in the national figures

Due to its high concentration of population, transport infrastructures and activities, the Île-de-France region accounts for 29% of the national figure for the social cost of noise (€147.1 bn/year). This significant contribution of the Ile-de-France region to the national cost of noise is to be compared with the economic weight of the Ile-de-France (30% of national GDP), which is much greater than the share represented by the Ile-de-France in the French metropolitan population (18%) or even in jobs (23%). With 9 million people in the Ile-de-France region exposed to levels above at least one of the values recommended by the WHO for transport noise, including 1.7 million exposed to levels above at least one French regulatory limit value, the Ile-de-France region accounts for 27% of the national cost associated with transport noise (€97.8 bn/year): 23% for road noise, 34% for rail noise and 68% for air traffic noise. With 42% of Ile-de-France residents quoting neighbourhood noise as the main source of annoyance at home, just after transport noise (49%) [16], the region accounts for 40% of the national figure (€26.3 bn/year) for this item. The regional costing of noise at work or at school represents 25% of the national costing (€21 bn/year). Finally, the regional costing of cross-sectoral expenditure incurred in connection with the treatment and prevention of noise represents 41% of the national costing (€2 bn/year) associated with this item.

5. DISCUSSION

A certain number of estimates made in the context of these studies should be considered with caution due to the lack of data, the uncertainties of the calculations or the use of knowledge that is still fragile. Some of the health effects of noise that have been included are still insufficiently documented and need to be further studied in order to refine our knowledge of the dose-effect relationships. This is the case, for example, for disturbances of the metabolic system, cardiovascular diseases or psychological disorders generated by noise. The social costs of neighbourhood noise and occupational work would require further studies to improve the estimates.

In addition, some health effects could not be included in the study at this stage, although it seems that noise may play a role. Recent studies [33, 34] indicate a potential link between long-term exposure to noise and the risk of developing Alzheimer's disease, due to the cognitive decline promoted by the annoyance and sleep disturbance caused by noise.

Some of the economic consequences of noise have not been addressed in this study either, due to the lack of available methodology to assess them. For example, the cost associated with the loss of land use possibilities due to noise exposure: due to certain regulations limiting construction near a noise source, especially around airports, or due to the reduction in the attractiveness of a territory because of noise pollution, certain areas become unfit for residential construction or for the installation of an economic activity.

Finally, this study has focused on the consequences of noise on human health and the economy, and has not been extended to other ecosystems. However, it is recognised that noise also has important consequences for biodiversity, and in particular for animals that may have difficulties in communicating due to noise pollution, that may have changes in their survival capacity and behaviour, or whose metabolism may be affected. It is reasonable to assume that the consequences of noise on ecosystems have a significant cost, notably by disturbing their equilibrium and state of health, and indirectly by affecting the ecosystem services that can be provided, for example in the case of the agricultural and tourism sectors.

6. CONCLUSIONS

Although this type of study still has a number of limitations, it nevertheless opens up a vast prospective field in the area of appropriation of the issues involved in improving the noise environment. It thus provides robust elements that can now be used to compare the financial cost of noise prevention and mitigation measures with the resulting social benefits in terms of improved well-being of the population and avoided costs for the community as a whole. The systematisation of cost-benefit analyses in the field of combating noise will make it possible to highlight the relevance of noise reduction or soundscape preservation actions, as the social benefits are generally far greater than the investment costs involved, especially as the solutions implemented often have significant co-benefits with other ecological or social issues.

7. REFERENCES

[1] WHO. (2018). Environmental Noise Guidelines for the European Regions.
[2] EY, ADEME, CNB. (2016). Analyse bibliographique des travaux français et européens - le coût social des pollutions sonores.
[3] ADEME, I CARE & CONSULT, ÉNERGIES DEMAIN, DOUILLET Maia, SIPOS Gala, DELUGIN Léna, BULLIOT Benoît, REMONTET Lucas, BIDAULT Elsa. (2021). Estimation du coût social du bruit en France et analyse de mesures d'évitement simultané du bruit et de la pollution de l'air. 80 pages.
[4] BRUITPARIF. (2021). Le coût social du bruit en Île-de-France.
[5] Evrard, A. L.-A. (2020). Effets de l'exposition au bruit des avions sur la santé : résultats, à l'inclusion, de l'étude DEBATS. Bulletin épidémiologique hebdomadaire.
[6] Lefèvre, M. C. (2020). Understanding the relationship between air traffic noise exposure and annoyance in populations living near airports in France. Environment International.
[7] Stansfeld, S. B.-B. (2005). Aircraft and road traffic noise and children's cognition and health: a cross-national study. Lancet.
[8] Foraster, M. E.-H. (2018). Long-term exposure to transportation noise and its association with adiposity markers and development of obesity. Environment international, pp. 879-889.
[9] Eze, I. C.-H. (2017). Long-term exposure to transportation noise and air pollution in relation to incident diabetes in the SAPALDIA study. International journal of epidemiology, pp. 1115-1125.
[10] Lan, Y. R. (2020). Transportation noise exposure and anxiety: a systematic review and meta-analysis. Environmental research.
[11] WHO. (2004). Global burden of disease 2004 Update: disability weights for diseases and conditions.
[12] Global Burden of Disease Collaborative Network. (2018). Global Burden of Disease Study 2017 (GBD 2017) Disability Weights.

[13] OECD. (2019). Economics of Prevention: Final Report - Estimating the Economic Burden Associated with High Body Mass Index and Harmful Alcohol Use.
[14] Commissariat général à la stratégie et à la prospective. (2013). Evaluation socioéconomique des investissements publics.
[15] Okokon, E. O.-T. (2018). Traffic noise, noise annoyance and psychotropic medication. Environment International, pp. 287-294.
[16] CRÉDOC, BRUITPARIF. (2017). Qualité de vie et nuisances sonores : opinion et comportements des Franciliens.
[17] Hafner, M., Stepanek, M., Taylor, J., Troxel, W. M., & Van Stolk, C. (2017). Why sleep matters—the economic costs of insufficient sleep: a cross-country comparative analysis. Rand health quarterly.
[18] Sedoarisoa, N. D. (2017). Prix de l'immobilier et proximité de la plate-forme aéroportuaire de Paris–Charles-de-Gaulle (CDG). L'Espace Géographique, pp. 61-78.
[19] Sedoarisoa, N. D. (2017). Quelle valeur économique de la réduction du bruit ferroviaire par les murs antibruit ? Le cas de deux communes en Seine Saint-Denis. FAERE.
[20] Le Boennec, R. S. (2017). The impact of air pollution and noise on the real estate market. The case of the 2013 European Green Capital: Nantes, France.
[21] Beimer, W. M. (2017). Noise effects and real estate prices: A simultaneous analysis of different noise sources. Transportation Research Part D, pp. 282–286.
[22] IFOP. (2014). Les Français et les nuisances sonores.
[23] Jensen, H. A. (2018). Neighbour and traffic noise annoyance: a nationwide study of associated mental health and perceived stress. European journal of public health, pp. 1050-1055.
[24] Lee, J. (2020). Neighborhood noise.
[25] Liu, Y. X. (2017). Community response to construction noise in three central cities of Zhejiang province, China. Environmental Pollution.
[26] Xiao, J. L. (2016). DALY-based health risk assessment of construction noise in Beijing, China. International journal of environmental research and public health.
[27] J. de Vervasdoué, L. Hartmann, Impact Economique du Déficit Auditif en France et dans les Pays Développés – Revue de la littérature scientifique 2005-2015, rapport final, mars 2016.
[28] DARES. (2007). Premières synthèses Informations - Accidents et conditions de travail.
[29] IFOP, JNA Association. (2019). Bruit, santé auditive et qualité de vie au travail - Enquête auprès des actifs exerçant une activité professionnelle.
[30] Ecophon. (2019). L'impact du bruit dans l'enseignement.
[31] Bruitparif, CidB, (2009). Campagne de mesure et de sensibilisation au bruit au sein des lycées d'Ile-de-France, Rapport de synthèse.
[32] Si, S. L. (2020). Productivity burden of occupational noise-induced hearing loss in Australia: a Life Table Modelling Study. International journal of environmental research and public health.
[33] Wallas, A. E. (2017). Road traffic noise and determinants of saliva cortisol levels among adolescents. International Journal of Hygiene and Environmental Health.
[34] Weuve, J. D. (2020). Long-term community noise exposure in relation to dementia, cognition, and cognitive decline in older adults. Alzheimer's & Dementia.