Hazards and the environment

Science topic n°3

How to **deal** with **urban noise**?

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Hazards and the environment

Introduction

1 Annoyance and noise effects on humans

2 Assessing the noise impact of electric and hybrid vehicles

3 Developing quieter pavement surfacings

4 Mitigating railway noise

5 Studying noise at urban level

6 Urban vegetation to combat noise pollution

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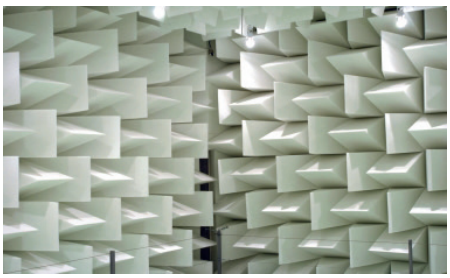
HOW TO DEAL WITH URBAN NOISE?

By Judicaël Picaut,
LAE[1] Laboratory Director
AME[2] Department

Noise is a nuisance that affects two out of three people in France. The problem is particularly acute in urban areas because of noise outside buildings, caused by transport and worksites, for example. In more concrete terms, noise is considered to be very irritating for 25% and may cause 20% of the population to move home[3]. Noise can also have a variety of serious health impacts on residents.

Starting in 1992, the public authorities have introduced a number of regulations to manage noise (Act No. 92-1444)[4]. The Act was strengthened in 2002 by a European Directive[5]. In addition to local noise level measurements, in many cases, a key aspect of noise management consists in predicting the impact of the noise that will be generated by a new facility such as a new road infrastructure or an industrial area, for example.

However, to do this, it is necessary to describe and quantify sources of noise, noise propagation in built-up areas and how noise affects residents. The importance of this issue for society means that the study of noise pollution in the environment, particularly the urban environment, is an extremely important research topic at IFSTTAR.



▲ Room semi-anechoic "Marin Mersenne" (SSA): insulated chamber whose walls and ceiling are padded to absorb the incident sound energy.

Research into the characterisation of the sources of urban noise – road or rail – is then extremely important. New generation road vehicles such as hybrid and electric vehicles, which are often thought to make less noise, have recently started to join the vehicle fleet.

These vehicles have quieter engines, so rolling noise, caused by contact between the tire and the pavement becomes dominant. This emerging phenomenon is stimulating new research which sets out, in particular, to develop road surfaces which are "optimised" for noise. With regard to rail transport, the noise generated by trams and trains is produced from a variety of sources. These include squeal noise, which may be very loud and require appropriate investigation.

While the study of noise propagation in urban areas has resulted in a large amount of research in the last 20 years, new planning practices (implementing 30km/h zones, creating exclusive right-of-way transport systems, fostering multimodal travel practices, etc.) make it necessary to revise the methods traditionally employed in environmental acoustics.

The development of noise predicting models that take account of the traffic flows at different times for different transport modalities, at large urban scales has thus become essential, in particular in order to evaluate public environmental protection policies.

New urban planting policies are another example of planning measures. Reintroducing vegetation in urban areas was initially envisaged because of its many benefits in terms of, for example, resident comfort, building aesthetics, the reduction of urban heat islands and the absorption of pollution, but it has been found that parks or green facades or roofs can also reduce noise levels.

To sum up, the strengthening of regulations, linked to changes in vehicles and planning practices will require a considerable amount of research in the future, in order to meet the increasing demands of society.

1. LAE: Environmental Acoustics Laboratory
2. AME: Planning, Mobilities and Environment Department
3. http://www.tns-sofres.com/points-de-vue/051192AD6B984C4ABE87B0B7FB887AE3.aspx
4. http://legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000179257
5. http://www.legifrance.gouv.fr/affichTexte.docidTexte=JORFTEXT000000337482&dateTexte=20130123

Video (FR)

Credit: Ifsttar

IFSTTAR'S COLLECTION
April 2014

1 UNDERSTANDING THE DISTURBANCE AND THE EFFECTS CAUSED BY NOISE

By Patricia Champelovier,
AME[1] Department, LTE[2] Laboratory

More than half the people in the world live in cities where their health and general well-being suffer from the adverse effects noise pollution. The first step towards understanding these effects is to assess how noise is experienced by residents living near transport infrastructure. The next is to understand, predict and make allowances for the way individuals react to a change in their noise environment. The final step is to help in the choice of solutions that meet goals as regards sustainability and quality of life.

Noise perception – not just a response to the level of noise

Noise is deemed to be a type of pollution: it is an "unwelcome emission of sound"[3]. This definition is made up of two parts: one is physical – what the ear hears –, and one psychological – what the individual feels. For psychologists, investigating perception involves examining how individuals interpret the signals they receive from the environment. This depends on our representations, knowledge, previous experience, expectations and motivations. What we perceive is not simply the reflection of the physical world[4].

▼ Recording and measuring system of urban noise.

The effects of noise: the connection between disturbance and health

Noise causes stress for individuals. Long-term exposure can increase the risk of chronic health impacts (particularly cardiovascular disorders) and increase consumption of certain medications.

The effects of noise on quality of life are multiple, ranging from interfering with speech to impairing sleep quality and performance. They can also modify behaviours within the home (closing windows, the use of certain rooms and external space, sound insulation, moving home, etc.).

Disturbance from noise is considered to be a subjective sensation. It is related to the characteristics of the noise, and also influenced by individual factors (depending on the dwelling, sensitivity to noise, experience of noise, being a transport user or not) and depends on the type of housing and socio-cultural factors (representation of the source, expectations with regard to the public authorities).

Disturbance is assessed on the basis of questionnaires (verbal[5] or numerical scales of disturbance). The respondents' answers are then compared with noise exposure indices measured in their homes.

IFSTTAR has been conducting in *in situ* surveys for a good many years in order to assess the disturbance caused by transport noise (road traffic, trains and planes[6]). The LTE is currently involved in the question of exposure to multiple noise sources. The aim is to gain a better understanding of the mechanisms of perception and disturbance generated by complex noise situations, which are becoming increasingly common, especially in urban areas. Laboratory experiments have also been set up[7] 6 in order to simulate environmental situations, taken from real life or not, and collect subjects' assessments of them. The results of this research have provided us with a better understanding of noise disturbance. This is applied when new infrastructure is constructed and helps when drafting regulations to protect residents.

Plan du LSEE

▲ Environmental Simulation and Assessment Laboratory

1. AME: Planning, Mobilities and Environment Department
2. LTE: Transport and Environment Laboratory
3. Moser, G. (2009) Psychologie environnementale, éditions De Boeck, 298 p.
4. Bonnet, C., Ghiglione, R., Richard, JF. (1989), Traité de psychologie cognitive, Tome 1 : Perception, action, langage, éditions Dunod, 266 p.
5. Afnor – Norme ISO/TS 15666/2003 : Évaluation de la gêne causée par le bruit au moyen d'enquêtes sociales et d'enquêtes socio-acoustiques.
6. The LTE is currently involved in the project http://debats-avions.ifsttar.fr/ (epidemiological research led by the UMRESTTE Département TS2 which deals with the links between exposure to aircraft noise and health.
7. These experiments are being performed at the LSEE (Laboratory for Simulation and Appraisal of the Environment) an experimental facility that is part of the du LTE.

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April 2014

2 ASSESSING THE NOISE IMPACT OF ELECTRIC AND HYBRID VEHICLES

By Marie-Agnès Pallas,
AME[1] Department, LAE[2] Laboratory

Electric and hybrid vehicles take centre stage among environmentally-friendly vehicles[3]. In addition to generating less atmospheric pollution, they are also recognized as being very quiet in urban traffic conditions. This gives them the potential to reduce urban noise pollution.

The sources of light vehicle noise

The noise generated by vehicle passage has two main components: noise from the power train and rolling noise caused by contact when the tyre rolls over the pavement. There is little tyre-pavement contact noise at low speeds, but it becomes dominant when vehicles move faster. In the case of a vehicle with a conventional engine, either petrol or diesel, the noise from the power train dominates at low speed and therefore adds to noise pollution in urban areas. In the case of an electrically-powered vehicle (an electric vehicle, or a hybrid vehicle in fully electric mode), the engine noise is low, and the rolling noise is therefore the main source of noise over a large range of speeds. These vehicles have the advantage of being almost silent when stationary. It should nevertheless be remembered that vehicle manufacturers have developed some vehicles with conventional engines which also have a very low noise emissions. The noise emitted by electric and hybrid vehicles is therefore the subject of many studies, at the LAE in particular, in the framework of the FOREVER project[4].

Heavy vehicles are also involved

Heavy vehicle manufacturers are also developing electric or hybrid vehicles, for example delivery lorries or household refuse collection vehicles. In this connection, the LAE taken part in the acoustic evaluation of a hybrid lorry developed in the framework of the GEODE project[5]. As far as public transport is concerned, the authorities in many cities are becoming increasingly interested in hybrid or fully electric buses, and manufacturers are developing new technologies to increase the electrical range of vehicles. This explains LAE's participation in the ElLiSup project[6] which aimed to develop quick charge hybrid or electric buses. These projects highlight the benefits provided by the fully electric mode, while acoustic performance in the hybrid mode depends very much on the hybridization technologies employed.

◀ GEODE project - acoustic emission measure of a vehicle

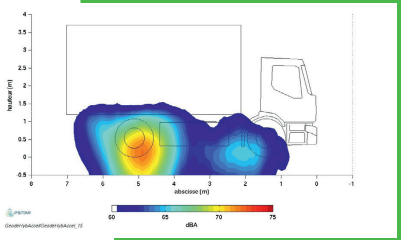
Impact on traffic as a whole

While a very significant noise reduction can be achieved for a single electric vehicle, there will only be a marked impact for traffic as a whole if it contains a high proportion of low-noise vehicles. This is due to the characteristic arithmetic that applies to noise levels, which are expressed in decibels. If we imagine a situation in which half of the urban traffic mix consists of electric vehicles whose noise emissions are 10 dB(A) lower and the other half consists of conventional vehicles, the overall noise reduction compared with conventional traffic will only be few decibels and barely noticeable.

Reducing or increasing noise?

The issue of the risk silent vehicles pose for other road users has been raised because they are so quiet at low speeds that pedestrians and cyclists may fail to notice them. In some countries it is advisory or compulsory for vehicles to emit warning signs when travelling at low speeds to make the vehicles more audible. Achieving both the safety of road users and noise reductions for residents therefore opens up a new area for urban noise research.

▼ Localizing the sources of noise on a hybrid lorry (GEODE project).



▲ The colour scale represents the acoustic power level, ranging from red (high) to blue (low).

1. AME: Planning, Mobilities and Environment Department
2. LAE: Environmental Acoustics Laboratory
3. A hybrid vehicle has both an internal combustion engine and an electric engine, one or other being used depending on the type of hybridization and the situation (speed, acceleration, battery charge level, etc.).
4. FOREVER project: http://forever.fehrl.org/
5. The GEODE project (GEstion Optimisée De l'Energie), financed by the FUI and Région Rhône-Alpes and managed by Renault Trucks.
6. The ELLiSup project (Bus Electrique à recharge rapide batteries Lithium et supercapacités) financed by ADEME and managed by Iveco Bus.

Pour aller plus loin

M.-A. Pallas, R. Chatagnon, J. Lelong, Évaluation du comportement et des performances acoustiques d'un camion hybride en conditions urbaines. Acoustique et Technique, 69, 16-22, 2012.
M.-A. Pallas, R. Chatagnon, J. Lelong, Noise emission and noise sources of a hybrid bus. Proceedings of Internoise 2013. Innsbrück, Austria, 2013.
M. A. Pallas, R. Chatagon, Véhicules électriques et hybrides : enjeux acoustiques. Acoustique et Technique, 78, pp. 43-51, 2015.

Credit: Ifsttar

Article Update: september 2017

IFSTTAR'S COLLECTION
April 2014

3 DEVELOPING QUIETER PAVEMENT SURFACINGS

By Michel Bérengier,
AME[1] Department, LAE[2] Laboratory

Recent years have seen the publication in France, and elsewhere in Europe, of a series of documents that put in place a strategy to reduce the noise from road transport ultimately by at least 30%. In this connection too, several European cities are interested in using quieter pavement surfaces in order to comply with European Directive 2002/49/CE.

▲ Continuous measurement of embedded system rolling noise.

Reducing noise levels at the source is still the best way of reducing the noise pollution affecting residents. As a high proportion of noise emissions are due to rolling noise (even in urban areas), two solutions spring to mind: reducing the proportion of noise generated by the tyre and reducing that generated by the pavement surfacing. IFSTTAR is focusing its research on the second option.

From "traditional" porous asphalts to asphalt concrete

In the past, porous asphalts (which in France are known as Béton Bitumineux Drainants – BBRd and which have 0/10 and 0/6 grading) were tested in urban areas. Even though they gave substantial acoustic gains immediately after laying, these were considerably reduced by clogging after a few years of service. These difficulties were mainly due to low traffic speeds which prevented self-maintenance of the porous course. It therefore became a matter of some urgency to carry out fresh research into other types of low-noise pavement structure. The outcome was a material with a very small particle size, Very Thin Asphaltic Overlay (Bitumineux à couche Très Mince – BBTM).

France's major road construction firms have increased their research into these new surfacings, focusing mainly on the grading and the composition of the binder. As a result, Very Thin Asphaltic Overlays with a grading of 0/6 or even 0/4 were trialled on public roads. These surfacings are of interest in terms of the rolling noise generated by vehicle passage (measured as laid down in the ISO 11819-1 standard). For example, a 0/4 Very Thin Asphaltic Overlay emits approximately 9 dB(A) less noise than a 0/10 reference Semi-Coarse Asphaltic Concrete. This improvement should be set against those obtained from 0/10 Porous Asphalt (3 dB(A)) and 0/6 Porous Asphalt (6 dB(A)). The long-term nature of these improvements nevertheless needs to be verified, particularly with regard to binder ageing.

A new generation of noise-optimized surfacings

In parallel with this, research has been conducted to design dense (non porous) wearing courses that provide noise reductions that are at least comparable with those obtained with "conventional" porous structures. Much of this research has been performed as part of the ADEME-backed DEUFRAKO Franco-German cooperation programme. The P2RN project (Prediction and Propagation of Rolling Noise) which came to an end in 2009 identified a theoretically optimal texture. The ODSurf project (which deals with the modelling and construction of an optimized dense low-noise wearing course) will be completed at the end of 2015 and is concerned with developing the necessary industrial processes and carrying out the various comparative tests.

1. AME: Planning, Mobilities and Environment Department
2. LAE: Environmental Acoustics Laboratory

▼ Sonoroute, an onboard measuring system continuously rolling noise.

Credit: Ifsttar

4 MITIGATING RAILWAY NOISE

By Olivier Chiello,
AME[1] Department, LAE[2] Laboratory

Living near a railway, a tramway or a Metro line can be testing for our ears. One way of reducing train passage noise is to install noise screens along the tracks or better insulate affected buildings. But the most direct, and in many cases the most effective, way is to take action at the source. But how?

Identifying sources of noise

At low speeds, most of the noise is caused by the drive units (engines, auxiliaries, ventilators). The rolling noise caused by contact between the wheels and the rails begins to dominate at higher speeds. In the case of high speed trains, aerodynamic noise appears above 300km/h. Other sources make a contribution in specific situations, for example screeching on tight bends or braking noises on arrival at a station. In the worst cases, noise levels near trains can exceed 100 dB(A)! Last, vibrations that are transmitted by the soil, bridges or tunnels can pose problems in some situations, particularly in urban environments.

In order to localize and characterize sources, we frequently use microphone antennae. In the case of railways, a large proportion of the noise is due to the rails which can vibrate over a length of several tens of metres. However, conventional antennae are not appropriate for spatially extended sound sources of this type. In view of this, the LAE has conducted research with a view to developing alternative methods for identifying their contribution more accurately[3].

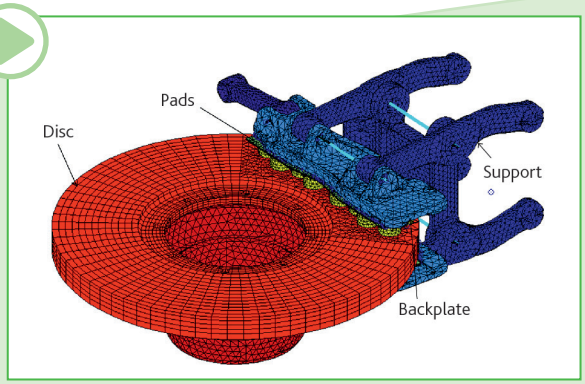
Understanding noise generation mechanisms

In the last 20 years a considerable amount of research has been conducted into rolling noise. We now know that it is caused by irregularities in the contact surfaces that set up vibrations in both the wheels and the track. In comparison, our understanding of the other mechanisms remains limited.

For example, explaining the origin of screeching noises remains a real challenge. In the framework of the AcouFren research programme[4], the LAE is carryied out research with this in mind in partnership with the Laboratory of Tribology

Animation

Acoufren project: a numerical pattern of railway disc brakes



and Systems Dynamics at the École Centrale de Lyon[5]. By implementing a strategy that combines modelling and experimentation, this work has made significant advances which have demonstrated that the screeching noises are caused by a complex phenomenon of vibrational instability affecting structures that are in frictional contact.

Developing and testing solutions

We now have effective solutions to the problem of rolling noise: first, the interface between the wheel and the rail must be kept in good condition (by using composition brake shoes), vibrations must then be attenuated (by installing dynamic vibration absorbers on the rails). The challenge today is to optimize these solutions by taking account of the other constraints.

Research into ways of reducing the other sources of noise is frequently empirical. The development of optimized solutions therefore goes hand-in-hand with a better understanding of noise generation mechanisms. In the case of squeal noise caused by braking, for example, one part of the AcouFren project was to develop and test quieter brake linings. Software has been developed to test how the mechanical characteristics of linings affect noise emissions[6].

▲ Localization and characterization of tram noise sources through a microphone antenna

1. AME: Planning, Mobilities and Environment Department
2. LAE: Environmental Acoustics Laboratory
3. Baldrik Faure, Caractérisation du rayonnement acoustique d'un rail à l'aide d'un réseau de microphones, thèse de doctorat de l'Université de Grenoble, 2011.
4. « AcouFren », Outils d'aide à la spécification et à la conception de freins à disques ferroviaires optimisés vis-à-vis du crissement, programme de recherche 2010-2014, financé par l'ADEME et piloté par la SNCF.
5. Andréa Loyer, Étude numérique et expérimentale du crissement des systèmes de freinage ferroviaires, thèse de doctorat de l'École Centrale de Lyon, 2012.
6. Chiello *et al.*, Squeal noise generated by railway disc brakes: experiments and stability computations on large industrial models, Proceedings of the 21st International Congress on Acoustics, Montréal, 2013.

Credit: Ifsttar

Article Update: september 2017

IFSTTAR'S COLLECTION
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5 STUDYING NOISE AT URBAN LEVEL

By Joël Lelong,
AME[1] Department, LAE[2] Laboratory

European Directive 2002/49/CE on the evaluation and management of environmental noise highlights the need to inform residents about the hazards and impacts of environmental noise and stresses the need to adopt noise prevention and mitigation action plans. In particular, it compels large cities to produce noise maps. In France, this requirement to take account of noise, especially road noise, applies to every conurbation that needs to implement an Urban Travel Plan (Plan de Déplacement Urbain (PDU)) as laid down by the Domestic Transport Policy Act (LOTI).

From noise calculations to an integrated approach using Geographic Information Systems (GIS)

Standardized methods are available that meet these legal obligations, particularly the production and dissemination of noise maps for major conurbations. These maps are based on simplified urban noise propagation models, and use sound source models, for roads in particular, that apply average traffic conditions.

However, recent studies show that noise is only one of many factors that create the disturbance individuals experience: lighting, olfactory and aeraulic conditions also play a role in characterizing a location. Today, in order to understand the urban environment it has become essential to combine data of different types, i.e. physical (thermal, acoustic, luminous, etc.) and "societal" (demography, the property market, etc.). For example, recent research, conducted in particular at the IRSTV (Institute for Research on Urban Sciences and Techniques) in collaboration with IFSTTAR, has attempted to develop integrated multi-physics approaches within a GIS, in order to provide computation, representation and information dissemination tools for the various stakeholders (the scientific community, local government and residents).

▲ Sound exposure level (sound level in relation to population density) for individual buildings, in Nantes for 2008. Map produced by IFSTTAR using the OrbisGIS software, published on the IRSTV's Webcarto servic (www.orbisgis.org).

From static modelling to a dynamic description of urban noise

In the case of urban traffic noise, although the currently available tools meet the applicable regulations, which are based on a static description of traffic, their limitations are often apparent when more detailed data are required (quantification of noise emergence, consideration of the dynamics of traffic noise). Difficulties are also encountered when the impact of certain design changes needs to be evaluated, for example when intersections or the type of road are modified, or when exclusive rights-of-way are created for public transport.

This situation has led us to develop a special approach based on the dynamic modelling of traffic flow. This was developed in the Transport and Traffic Engineering Laboratory (LICIT ENTPE/IFSTTAR) and allows us to evaluate fluctuations in the traffic, caused by variations in flow, reductions or increases in capacity (as a result of the characteristics of the road), or traffic signals.

Credit: Ifsttar

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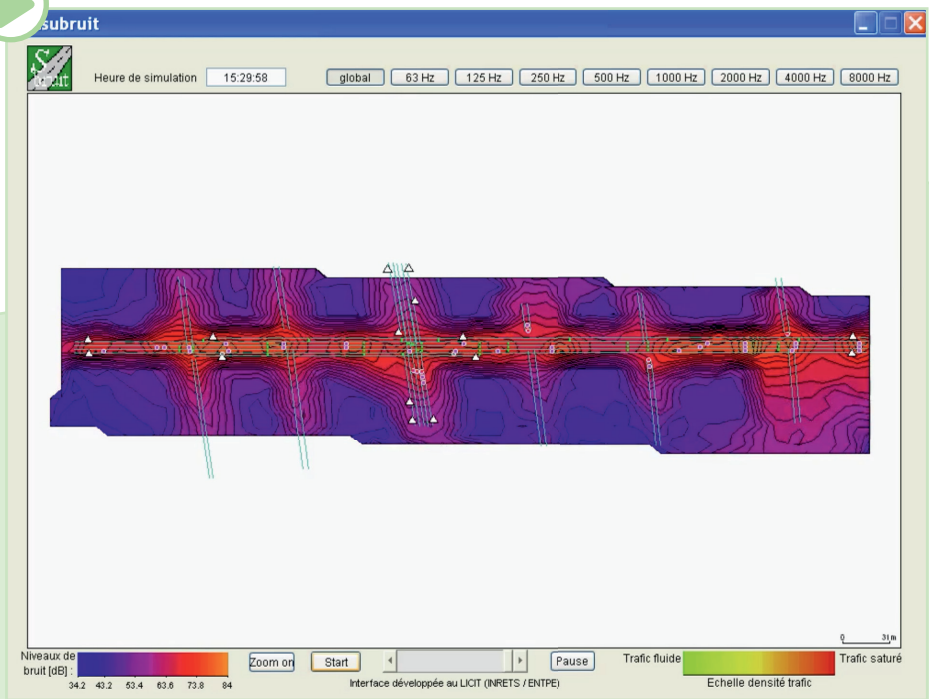
STUDYING NOISE AT URBAN LEVEL (END)

This type of model is also able to simulate traffic flow within complex intersections, or the behaviour of clean vehicles, such as buses, in urban areas as these have different kinematic characteristics from light vehicles.

LAE's research is concerned both with characterizing the acoustic emissions of vehicles in the conditions of real use (taking account of transitory kinematic factors and estimating driving behaviour), and describing acoustic propagation in complex environments such as urban areas.

Video (FR)



Noise dynamic mapping on Lyon Lafayette Avenue.

They have led to the development of a comprehensive model that is able to estimate noise levels at frontages at a very fine-grained temporal scale, of approximately 1 second.
This tool has been experimentally validated on a section of urban road in Lyon and a district level version is currently in the development phase. This includes new functionalities such as tramline modelling, with the ability to integrate the behaviour of intersection traffic control systems and the mode's noise emissions.

"This work, which is being conducted in close partnership with other teams in the French Scientific and Technical Network – RST (including the CSTB), will ultimately provide local authorities with a robust tool for evaluating the environmental impact of a conurbation's traffic control strategies or traffic management plans."

1. AME: Planning, Mobilities and Environment Department
2. LAE: Environmental Acoustics Laboratory

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April 2014

6 URBAN VEGETATION TO COMBAT NOISE POLLUTION

By Benoît Gauvreau et Gwenaël Guillaume,
AME[1] Department, LAE[2] Laboratory

From reducing heat islands to the impact of vegetation on noise

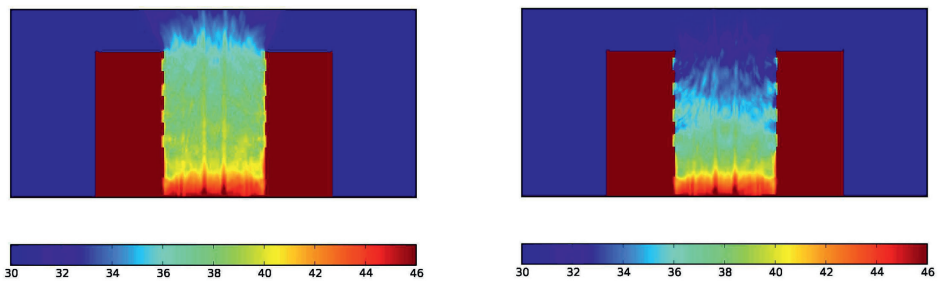
The growth of urban areas, which increases the size of artificially covered areas to the detriment of naturally covered ones, frequently has impacts on environmental quality, creating urban heat islands, atmospheric pollution, noise, etc. When it is technically feasible, the creation of green facades or roofs is a possible way of contributing to sustainable urban development.

From the purely acoustic standpoint, the effect of vegetation on urban noise environments can be considered at local, street, level, at the overall level of the city, with the district level between the two. The effects in question can be divided into two types for each of these spatial scales: direct effects (due to the absorbent properties of vegetation, particularly the substrate) and indirect effects (because they are responsible for changes in the movement of air and temperature gradients, which have an indirect impact on noise propagation). The effects in question have been measured in previous studies, in what is essentially a theoretical and numerical manner, for a limited number of spatial configurations and scales (some studies describe an experimental validation using a physical model and *in situ* measurements).

Addition is required in this field in order to evaluate – numerically and experimentally – the influence of vegetation and the weather on urban noise environments, from the scale of the street to that of the district. Taking these new levels of complexity into account in the models developed by IFSTTAR requires development work to extend their scope of application.

The LAE has carried out this work mainly in the framework of the National Research Agency "VegDUD" project (2010-2014) which is managed by the IRSTV, in which the role of vegetation in sustainable urban development is analysed by an approach that combines

▼ Mapping of noise pressure levels in a street with (right picture) and without (left picture) urban vegetation - VegDUD project (2010 - 2014).
Red color : more noisy and blue color : less noisy.



climatology, hydrology, energy conservation and ambiances. The research in question has quantified the impact on the acoustic ambiance of these alternative practices for both private and public spaces, in particular by using classical physical indicators such as noise levels and reverberation times.

From urban noise reduction to the environmental description of districts

The ANR "EUREQUA" project (2012-2016) does not merely study the influence of vegetation on urban ambiances, it also sets out to objectivise and evaluate the environmental quality of a district by identifying relevant criteria and observable factors.

These serve to characterise the physical environment (climate, acoustics, air quality), and are used by residents and users to evaluate the living environment.

These two cross-disciplinary projects bring together specialists from many fields (town planners, sociologists, psychologists, numerical analysts, etc.) and different research fields (meteorology, hydrology, acoustics, climatic comfort, pollution, etc.). The ultimate aim of the project is to evaluate the impact of various urban planning scenarios (introduction of vegetation into the urban fabric, regeneration of a district, modification of the road traffic network, etc.), working in collaboration with bodies such as (Météo-France, École Centrale de Nantes, CEREA, LAVUE, CERMA, IRSTV, LISST, LPED, etc.). This is part of a comprehensive systems-based approach that takes account of the behaviours of users (residents and visitors), and examines their relationship with the environment in a sensitive and socially aware manner (surveys, commentated routes, etc.).

1. AME: Planning, Mobilities and Environment Department
2. LAE: Environmental Acoustics Laboratory

▶ VegDUD project (2010-2014) - *In-situ* Measurements of acoustic properties of a vegetated cover.

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