ABACUS ON OPERATIONAL CONTEXT ON NOISE LOW EMISSION ZONE

ACTION A.1

Life MONZA

Methodologies fOr Noise low emission Zones introduction And management

LIFE15 ENV/IT/000586

LIFE MONZA

Methodologies fOr Noise low emission Zones introduction And management

Abacus on operational context on Noise Low Emission Zone

Deliverable	**Abacus on operational context on Noise Low Emission Zone**
Action/Sub-action	Action A1 - Operational context for Noise Low Emission Zones (LEZ) detection and management
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1. Introduction

LIFE MONZA project

The introduction of Low Emission Zones, urban areas subject to road traffic restrictions in order to ensure compliance with the air pollutants limit values, set by the European Directive on ambient air quality (2008/50/EC), is a common and well-established action in the administrative government of the cities and the impacts on air quality improvement are widely analyzed, whereas the effects and benefits concerning the noise have not been addressed in a comprehensive manner.
Currently, noise is a major environmental health problem in Europe and road traffic is the most dominant source of environmental noise with an estimated 125 million people[1] affected by noise levels greater than 55 dB L_{den}[2].
At this time, there is a lack of a comprehensive and integrated administration process about LEZs. The definition, the criteria for analysis and the management methods of a Noise Low Emission Zone are not clearly expressed and shared yet.
LIFE MONZA project (Methodologies fOr Noise low emission Zones introduction And management - LIFE15 ENV/ IT/000586) addresses these issues. The first objective of the project is to introduce an easy-replicable method, and related guidelines, for the identification and the management of the Noise Low Emission Zone, an urban area subject to traffic restrictions, whose impacts and benefits regarding noise issues will be analyzed and tested in the pilot area of the city of Monza, located in North Italy.
The second objective regards specific *top-down measures*, adopted by the municipality and able to turn up the area in a permanent Noise LEZ, concerning traffic management, road paving substitution and introduction of two pedestrian crossings. The third objective is to reduce the average noise levels in the pilot area of Libertà district, with positive complementary effects also on the air quality and benefits on wellbeing conditions of inhabitants.
The fourth objective is to involve people in an active management system of a more sustainable lifestyle choices *(bottom-up measures)*, related to the reduction of noise and the improvement of air quality and wellbeing conditions, in their living and working environment. In order to encourage the local community involvement and to strengthen the dialogue between citizens and public bodies, many activities will be carried out, as meetings in primary and high schools, in order to raise awareness about noise effects, and also ideas contests for Noise LEZ picture and logo and questionnaires on quality of life and noise perception. A mobile app to manage voluntary and sustainable actions and to measure benefits and concrete changes in people lifestyle will be developed.
In order to contribute to the implementation of the European directives, avoiding duplications and overlaps, detection of the synergies existing between the issues related to noise pollution and air quality will be tested during the project.
The methodology will contribute to the implementation of the EU Directive 2002/49/EC, related to the assessment and management of environmental noise (Environmental Noise Directive - END), which introduces noise action plans, designed to manage noise issues and effect, including noise reduction if necessary.
The END does not provide a definition of LEZ in relation to noise and it is not considered as action to take into account in noise action plan drafting. Annex V of the Directive, *Minimum requirements for action plans*, suggests some examples of actions that competent authorities should taken into account, as traffic planning and land-use planning and those issues are involved in Noise LEZ introduction and management. Project results, defining criteria for Noise LEZ introduction and management, and related guideline, will contribute to increase the types of actions to carry on for noise action plans set out in Annex V of the Directive.

[1] Noise in Europe 2014. EEA Report- No 10/2014 European Environment Agency
[2] Lden: day-evening-night Level

Action A1 – *Operational context for Noise Low Emission Zones (LEZ) detection and management*

Action A1 is a preparatory action of LIFE MONZA project. It is structured in five sub-actions and it foresees a state-of-the-art review about the legislative and technical requirements on noise LEZ as well as the most up-to-date noise and air quality monitoring systems, including a scientific review on the suitable health indicators of the effects due to noise and air pollution and the analysis of the state of the art about possible interventions into LEZ areas and their effects on air quality, noise and health.
The beneficiary responsible for the implementation of this action is ISPRA. The action is divided in 5 sub-actions, each one coordinated by one associated beneficiary:
A1.1 Legal and Environmental framework for Noise LEZ introduction - MONZA
A1.2 Operational context: Noise Monitoring Systems - ISPRA
A1.3 Operational context: Air Quality Monitoring Systems - ISPRA
A1.4 Operational context: Health indicators - UNIFI
A1.5 Operational context: interventions and expected effects on air quality, noise and health – VIENROSE

The deliverable provided by the action A1 is the *Abacus on operational context on Noise Low Emission Zone*.

2. Abacus on operational context on Noise Low Emission Zone

The *Abacus on operational context on Noise Low Emission Zone* is structured in five sections dedicated to the following topics: A1.1 Legal and environmental framework for noise LEZ introduction; A1.2 Operational context: noise monitoring system; A1.3 Operational context: air quality monitoring system; A1.4 Operational context: health indicators; A1.5 Operational context: interventions and expected effects on air quality, noise and health. It is composed by data sheets, containing the main information about the topics covered. For each specific issue, the complete information is provided in five Reports, which are the annexes of this deliverable.
Following, the main contents covered by each topics and sections:

A1.1 - *Legal and Environmental framework for Noise LEZ introduction*

Action A.1 is aimed at developing a state-of-the-art review about the legislative and technical requirements on noise LEX, in order to update the current state of knowledge about the normative framework concerning environmental and acoustic pollution, on the one hand, and restrictions to circulation in some areas, on the other.
More specifically, in Sub Action A.1.1. Comune of Monza has the task to describe the normative framework regulating Municipalities activities when measures aimed at reducing acoustic and environmental pollution are decided.
The city of Monza has complied with the European and national laws aimed at noise reduction.
In 2013 the City Government approved the noise mapping and the connected action plan, developed and updated according to the Environmental Noise Directive 2002/49/EC (END). This was related to the assessment and management of environmental noise, which includes several measures to reduce noise in the city, among which the creation of a Limited Traffic Area for trucks, interventions on the city road system and on public buildings through the replacement of windows in order to protect from noise exposure.
In 2014 the acoustic zoning plan was approved and consists in an instrument which defines noise limits in different city areas. It includes city policies addressed to preserve public health from noise pollution and to adopt medium term measures for noise reduction.
Again, in 2014, a license plate recognition system was implemented in order to control unauthorized accesses of vehicles within the Restricted Traffic Zone of the historical centre of the city.
These deliberations provide a good starting point to define the legal context, which needs to be framed in the environmental context where the city of Monza is located, from a geographical and climatic point of view.
Monza is an Italian town of 122,955 inhabitants, located in Lombardy, and capital of the province of Monza and Brianza, recently established. By population, the municipality of Monza is, therefore, the second most populous in Milan hinterland.
The city lies in Pianura Padana, on the southern edge of Brianza province and it is located at an altitude of 162 meters above sea level. The nearest big towns, located in the most immediate surroundings, are Milan, about 20 km, and Lecco and Como, located about 40 km north.
The whole area of Monza, but, more generally the entire Lombardy region, has to be seen in the wider context of the Po basin, which is characterized by particular orographic and meteorological conditions determining significant vulnerabilities under the profile of the air quality.
The Po Valley is characterized by a wide plain surrounded to the north, west and south by mountain ranges that extend up to high altitudes, thus determining climatological characteristics both from the physical and from the dynamic point of view .
In fact, the mainly flat territory surrounded by Mountains and hills and, above all, the persistence of unfavorable weather conditions due to the continental climate and the existing poor ventilation especially during the autumn and winter seasons, on the one hand inhibit the phenomena of dispersion, whilst, on the other, favour concentrations of some pollutants (in particular nitrogen oxides and thin poor, such as PM10 and PM2.5) and the occurrence of diffuse pollution situations, with the consequent risk of non-compliance with air quality limit values laid by the rules and regional planning instruments.
The complete information is available in **Technical Report - A1.1 Legal and Environmental framework for Noise LEZ introduction,** Annex 1 of this deliverable and the main contents are reported in the data sheets of this Abacus.

A1.2 - *Operational context: Noise Monitoring Systems*

Sub-action A1.2 requires an update of the most advanced noise smart monitoring solutions. LIFE MONZA project provides a noise monitoring phase planned in pilot area, in which the activities will be carried on referring to the standard methods, using sound level meters of class I precision, and also by developing and using a smart low-cost monitoring system.
The prototype system for noise smart monitoring activities will be developed (*Action B.3 Prototype of monitoring system for Noise LEZ design - data analysis techniques definition*) and implemented, in order to be used as a continuous monitoring unit in the ex ante and ex post scenarios. A state of art about smart low-cost noise monitoring systems, in order to update the information on noise monitoring methods and to support the realization of the prototype, has been carried out by ISPRA, while the University of Florence will take care of the design of the system and VIE En.Ro.Se. will validate the network.
Currently, noise pollution is a growing concern. Some of the key messages of *Noise in Europe 2014 Report* highlights that environmental noise causes at least 10. 000 cases of premature death in Europe each year and almost 20 million adults are annoyed and a further 8 million suffer sleep disturbance due to environmental noise. Also, over 900.000 cases of hypertension are caused by environmental noise each year and noise causes 43.000 hospital admissions in Europe per year. The directive 2002/49/EC, related to the assessment and management of environmental noise[3] (Environmental Noise Directive – END) focuses on the assessment of people exposed to environmental noise, drafting strategic noise maps; on preventing and reducing environmental noise where necessary and preserving acoustic quality where it is good, drawing up action plans; on ensuring public information on environmental noise and its effects.

[3] http://ec.europa.eu/environment/noise/directive_en.htm

Regarding the noise assessment, there is the need to compare data of noise strategic maps, but the lack of a common assessment method causes significant inconsistencies in noise exposure data of different Member States and between the two implementation steps of the directive. European Commission has organized the Common Noise aSSessment methOdS project (CNOSSOS-EU), defining assessment methods for road, railway, aircraft and industrial noise, in order to allow the comparability of results across EU Member States. Application of the CNOSSOS methods will be mandatory for 2022 reporting round.

Noise is caused by a large amount of sources and there are many standardization methods able to assess noise impacts, shared at international level and applied in national legislations. International and national standards provide requirements, specifications, guidelines and technical reports, able to ensure reliability and quality of the results.

Technical specifications of noise monitoring systems and the comparability of the results are current and interesting issues. At EU level, FONOMOC[4], the FOcus group On NOise MOnitoring Cities, aims to exchange knowledge and experiences on noise monitoring in cities. It is a subgroup of Working Group Noise EUROCITIES, the network of major European cities. The Group works on identification of critical points in noise assessment activities and on developments and innovations of monitoring systems. Some topics discussed in meetings are related to systems for noise sources identification, real-time monitoring and mapping of environmental noise, noise sensor network, use of smartphones with annoyance applications, measurements by smartphones equipped with a low-cost MEMS (Micro Electro-Mechanical Systems) microphone.

The traditional method of environmental noise monitoring employs long and short measurements time periods, using expensive equipment for measurements and data management, while new noise monitoring methods, able to permit lower costs, long time measurements and quality output data, have been developed.

Recent developments of low-cost microphones and computing devices, together with the availability of web resources, give the opportunity to create noise measurement devices networks, defining a *"smart low-cost sound monitoring approach"*, which have been applied particularly in urban context, allowing, particularly at local scale, an acoustic characterization of urban areas.

Safeguarding the traditional standards of techniques and methods, mandatory by laws for noise monitoring activities, the smart monitoring systems, equipped with low-cost sensors, seem to be competitive, in some situations and under defined conditions.

Urban areas, as Noise LEZs, should be the correct scale for sensors networks applications and LIFE MONZA project, providing noise monitoring activities in pilot area conducting by traditional method and also by a prototype of smart low-cost monitoring system which will be developed, will give a contribute, analyzing the efficiency of the monitoring system and allowing data comparison.

An analysis of smart low-cost noise monitoring systems experiences and procedures, carried out in Europe, in order to allow updated information for the definition of the operational context related the noise monitoring issue and also to give advices for the development of the prototype of monitoring system for Noise LEZ provided by Action B.3 of LIFE MONZA project is treated in **Technical Report - A1.2 Operational context: Noise Monitoring Systems,** Annex 2 of this deliverable and the main contents are reported in the data sheets of this Abacus.

Sub-action A1.3 - *Operational context: Air Quality Monitoring Systems*

Air pollution: sources, status and trend legislation

Air pollution is considered as a major environmental risk for human health; it increases the incidence of a wide range of diseases and has several environmental impacts, damaging vegetation and ecosystems.

The road transport sector provides a significant contribution to the total anthropogenic emissions, together with other mobile sources, non industrial combustion plants and combustion in energy and transformation industries. Other undesired substances (known as secondary pollutants e.g. ozone) may be formed in the atmosphere due to chemical reaction between pollutant directly emitted.

Control of exposure to air pollutants requires public authorities actions at global, regional and local level. WHO produced and subsequently revised air quality guidelines (WHO, 2000, 2005) that contain recommendations of targets for air quality and limits for the concentration of selected air pollutants derived from epidemiological and toxicological evidence.

The Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe defined and established objectives for ambient air quality designed to avoid, prevent or reduce harmful effects on human health and the environment as a whole. The ambient air quality in Member States must be assessed on the basis of common methods and criteria. Results of the ambient air quality assessment should be used in order to help combat air pollution and nuisance and to monitor long-term trends and improvements. Air quality plans should be developed for zones within which concentration of pollutants in ambient air exceed the relevant air quality target value. Moreover it is mandatory for the member states to ensure that such information on ambient air quality is made available to the public.

The pollutants targeted by the 2008/50/EC directive include particulate matter ($PM_{2.5}$, PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and lead (Pb), while similar provisions were established for benzo(a)pirene, arsenic cadmium and nickel as high concern PM_{10} toxic components by the 2004/107/EC directive.

Over the last twenty five years, the emissions of pollutants in Europe and in Italy have generally decreased considerably. The major drivers for the trend are reductions in the industrial and road transport sectors, due to the implementation of various European Directives which introduced new technologies, plant emission limits, the limitation of sulphur content in liquid fuels and the shift to cleaner fuels (natural gas in place of coal and fuel oil). Nevertheless there are some relevant countertrend, for instance in Italy PM_{10} emissions from non industrial combustion plants, representing about 40% of the total, show a strong increase between 1990 and 2012, equal to 149% due to the increase of wood combustion for heating (ISPRA 2014).

Atmospheric pollution is an extremely complex phenomenon. The burden of pollutant resulting from human activities and natural source evolve in time and space trough the atmosphere. The transport, dilution, transformation and deposition mechanisms are driven by specific reactivity of the substances and the meteorological conditions, that are as well largely variable in time and space, and govern the dynamics of air pollutants after emission. This lead to a non-linear relationships between emission and outdoor air pollutants concentrations.

In the EU particulate matter, ozone and nitrogen oxides are the most critical pollutants, given the still high concentrations founded in the air, compared both with the European target and the WHO guidelines, despite the emissions reduction. A statistically significant moderate decreasing trend was found in the majority of the PM_{10}, and NO_2 Europe wide concentration time series, while any downward trend was found in the large majority of ozone time series.

Cities are major sources of pollution, due to city heating, energy production and transport. The majority of the people in the world live in urban areas.

Health effects of air pollution

Air pollution has been widely accepted and recognized by this time to have an impact in terms of cardio-vascular as well as respiratory diseases than can lead to premature mortality. Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide in 2012 (WHO, 2014).

Recently the International Agency for Research on Cancer (IARC) concluded that there is sufficient evidence that exposure to outdoor air pollution causes lung cancer. Particulate matter was evaluated separately and was also classified as carcinogenic to humans (IARC, 2013).

In recent years, 16 – 21 % of Europe's urban population may have been exposed to ambient PM_{10} concentrations above the EU limit set to protect human health. Up to 17 % of the population living in urban areas may have been exposed to levels of ozone that exceed the EU target value.

[4] https://workinggroupnoise.com/fonomoc/

Estimates of the health impacts attributable to exposure to air pollution indicate that PM2.5 concentrations in 2013 were responsible for about 467 000 premature deaths in Europe (41 countries), and around 436 000 in the EU-28, originating from long-term exposure. Fine particulate matter (PM2.5) in air has been estimated to reduce life expectancy in the EU by more than eight months. The estimated impacts on the population in the same 41 European countries of exposure to NO2 and O3 concentrations in 2013 were around 71 000 and 17 000 premature deaths per year, respectively, and in the EU 28 around 68 000 and 16 000 premature deaths per year, respectively (EEA, 2016).
Children and young adult represent the largest subpopulation of those susceptible to the adverse effects of air pollution. Compared to adults, they express a greater vulnerability, which can be explained by differences in the circumstances of exposure related to age, their activities, their child status, differences in lung anatomy and physiology, differences in the clinical expression of disease, and their organ maturity (WHO, 2013).
The complete information is available in **Technical Report - A1.3 Operational context: Air Quality Monitoring Systems,** Annex 3 of this deliverable and the main contents are reported in the data sheets of this Abacus.

Sub-action A1.4 - ***Operational context: Health indicators***

Sub-action A.1.4 consists in a state-of-the art review about the health indicators concerning quality of life and annoyance. The evidences from scientific literature have showed that environmental risk factors have a negative impact on health status. The methodology for calculating the burden of disease attributable to environmental noise was recently published by the World Health Organization, along with specific estimates of impact. Although no systematic and conclusive analysis about the effect of noise-control interventions on the health of the exposed population has been yet realized, the assumption of a clear link between exposure and related diseases makes appropriate the use of intermediate outcomes - and related actions, as in the case of the project - for the evaluation of impact, represented by the exposure changes .
The use of indicators of burden of disease to assess the effect of the measures implemented in the LIFE project, i.e. a synthetic indicator such as DALYs, is problematic and poorly informative because the diseases associated with environmental risk factors modify their occurrence in a long time, longer than that of the post-intervention follow-up. We believe, therefore, more appropriate to rely on proxy indicators of health status, modifiable in the study time-points, related to measurements of the quality of life.
Noisy environments may produce in exposed people several behavioral and social effects, affecting for example: daily behavioral patterns (inability to use outdoor areas and balconies, difficulty in listening of radio and television, presentation of complaints to the authorities); performance related to specific activities (i.e. school learning); social behavior (aggression, rudeness, etc.); social indicators (residential mobility, hospitalizations, consumption of drugs, road accidents, etc.); mood changes (i.e. sadness).Since this is a set of subjective feelings, the detection of annoyance is normally carried out through questionnaires administered to large groups of people. However, to date, in the literature there is no existence of an authoritative and validated questionnaire for the detection of this disturbance.
The complete information is available in **Technical Report - A1.4 Operational context: Health indicators,** Annex 4 of this deliverable and the main contents are reported in the data sheets of this Abacus.

Sub-action A1.5 - ***Operational context: interventions and expected effects on air quality, noise and health***

In sub-action A1.5 the analysis of the state of the art about possible interventions into LEZ areas and their effects on air quality, noise and health have been performed. The most recent available design solutions for noise abatement, air quality improvement and positive effects on health in urban areas have been collected.
In particular, a field survey among all literature, specialized magazine, technical papers, results coming from EU-founded projects has been carried out.
The survey has been mainly focused on the effects of: low noise paving, interventions on traffic regulation, strategic actions and noise barriers.
Referring to the choice of the typology of low noise paving, special attention has been reserved to results of “Leopoldo Project” (a project at regional level, coordinated by Tuscany Region) that gives guidelines for planning, construction, control and maintenance of the paving of the ordinary roads. At this time, the results of Leopoldo phase 1 (related to the implementation of low noise paving in extra-urban contexts) are available and consequently reported in the abacus. In the next future, results from the on-going Leopoldo phase 2 (related to the implementation of low noise paving in urban contexts) are expected to be collected (on the base of networking activities established with the Leopoldo project partners) and upgraded in the abacus.
Referring to other design solutions (Intervention on traffic regulation, strategic actions and noise barriers) special attention has been reserved to results of “Hush Project” (www.hush-project.eu) and “SONORUS Project” (www.fp7sonorus.eu).
Referring to noise barriers in urban contexts some interesting solutions have been found in the experiences and results of “QUADMAP Project” (www.quadmap.eu) and “SONORUS Project”.
Referring to the effects on health and safety special attention was paid on the report “Urban traffic calming and health”(November 2011) by National Collaborating Centre for Healthy Public Policy (Quebec).
The complete information is available in **Technical Report - A1.5 Operational context: interventions and expected effects on air quality, noise and health,** Annex 5 of this deliverable and the main contents are reported in the data sheets of this Abacus.

A1.1 Legal and Environmental Framework for Noise LEZ Introduction

Legal tools			
Type of Law	No. of law	Subject	Short summary
Civil Code (Royal Decree)	262/1942	Article 844	Noise immissions are allowed if not exceeding the threshold of normal tolerance
EC Directive	2002/49	Assessment and management of environmental noise	The Directive requires Member States to prepare and publish, every 5 years, **noise maps** and **noise management action plans** for agglomerations with more than 100,000 inhabitants
Italian Law	n.447/1995	Framework law on acoustic pollution	The law rules basic guidelines about protection of external and living environment from noise exposure
Decree of Prime Minister	14.11.1997	Limit values of sound sources	The decree disciplines limit values of emission and immission and quality and attention limits to consider when writing climate and acoustic impact assessments
Ministerial Decree	16.03.1998	Acoustic pollution detection and measuring techniques	The decree aims at harmonizing acoustic pollution detection and measuring techniques, paying attention to transport infrastructures emissions
Regional Law	10.08.2001 n. 13	Rules concerning acoustic pollution	The law rules protection of external and residential environment from acoustic pollution implementing law 447/1995. According to this law, Municipalities have to approve the acoustic classification of the territory. Some interventions are also planned in order to contain noise emission fromstreet traffic
Decree of President of Republic	30.03.2004 n. 142	Provisions to contain and prevent acoustic pollution from vehicular traffic	The decree proposes a different discipline of limit values for street infrastructures and defines the width of acoustic relevance bands
Legislative Decree	19.08.2005 n. 194	Actuation of EC Directive no. 2002/49 about Assessment and management of environmental noise	The decree transposes the EC Directive, introducing a sanctioning system

LEGAL FRAMEWORK AT EUROPEAN, NATIONAL, REGIONAL LEVEL ABOUT NOISE AND ACOUSTIC POLLUTION

Italy has a comprehensive regulatory framework that since the early 90 introduces precise criteria for the evaluation of the sound emissions which can be considered disruptive to people activities and sometimes harmful to health.

Article 844 of the Civil Code is the reference point for the assessment of an individual defense of the person and of his property against exposure to noise sources and refers to the threshold of "normal tolerance".

The regulatory system consists of the L 447/95 and the following decrees that fixed in the "acceptability criteria" the main reference point in the noise pollution assessment.

According to article 2 of Law 447/95 is called noise pollution, "the introduction of noise into the indoor or outdoor environment that is annoying or disturbing to rest and to human activities, endangering human health, deterioration of ecosystems, material goods, monuments and the indoor or outdoor environment, or interferes with the legitimate use of such environments ".

The framework of Law 447/95 constitutes the basic regulatory reference for the assessment of environmental noise by establishing:

- the fundamental principles with regard to noise protection of individuals and external environment;
- the responsibility of the State levels, of the regions, provinces and local authorities in the regulation, planning and noise control.

Protection of the external environment against adverse effects resulting from exposure to noise must be carried out, according to current legislation indicated, through the following actions:

- provision of specific noise acceptability limits, in terms of absolute values of output and input of noise events in the territory;
- development of acoustic zoning plans;
- drafting of noise action plans if the ambient noise levels exceed those of the exposure limit values and / or emission;
- establishment of action plans in the short, medium and long term aimed at linking the environmental noise levels at certain optimum values, so-called values of quality.

Measurements must be performed by a competent person in the field of environmental acoustics.

As far as laws concerning street circulation are concerned, Street Code is the regulatory framework and it has a specific article (no. 7) dealing with Limited Traffic Zones. These areas can be identified through a City Government decision, which can also subordinate the authorization to enter the LTZ to a fee. The identification of the right of accessing the LTZ. is rather "flexible" and it depends on the decision of the City Government which will take into account the actual situation (which obviously can vary from town to town and even within the same municipality) and the aims of mobility and protection of the public interest. The limitation of the circulation can be hourly and can relate to particular categories of users (residents, professional groups, public office holders, commercial enterprises, etc.) or, regardless of the users, categories of vehicles (private, freight, transport in question, etc.).

Legal tools			
Type of Law	No. of law	Subject	Short summary
Resolution of Regional Government	8299/2008	Identification of agglomerates of Bergamo, Brescia and Monza and competent authorities for the the determination and management of environmental noise	It establishes the Municipality as Local authority for the implementation of the acoustic zoning plan and of the consequent action plan
Resolution of Monza City council	n. 81/2014	Approval of Acoustic Zoning Plan	With this act limits are sets for the existing sound sources and environmental goals for specific areas are planned.
Resolution of City Government	no. 185/2016	Approval of Noise Action Plan	The plan Identifies measures aimed at reducing noise emissions

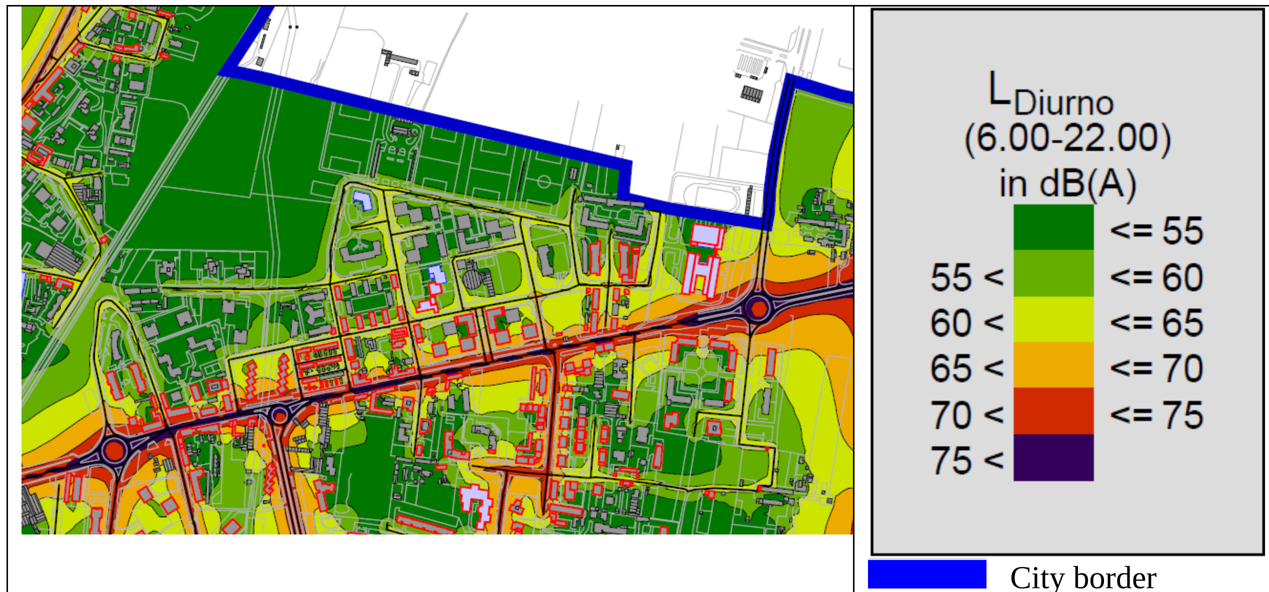


Figure A1.02
Source: Comune of Monza Acoustic Zoning Plan – Daily Exceedings – table 3
Link: http://www.comune.monza.it/it/comune/Documenti-e-Piani/Piano-rumore/

LEGAL FRAMEWORK AT REGIONAL AND LOCAL LEVEL ABOUT ACOUSTIC POLLUTION

The Municipality has prepared a noise map of its territory be accompanied by an action plan which aims at preventing and reducing environmental noise.

As required by Legislative Decree 194/2005 "Implementation of Directive 2002/49 / EC relating to the assessment and management of environmental noise" agglomerations (urban areas, identified by the region, with total population of more than 100,000 inhabitants) develop noise mapping of its territory and adopt Action Plans in order to prevent and reduce environmental noise where necessary and to avoid an increase in noise quiet areas.

Lombardy Region with Regional Council Resolution no. 8299/2008 identified the municipality of Monza as an agglomerate with responsibility for drawing up the noise mapping and Action Plans.

In 2014 the City Council approved the Acoustic Zoning Plan, a technical documents by which limits are set for the existing sound sources. Every City planning document (Plan of Territory Government, Urban Traffic Plan) has to comply with the Acoustic Zoning Plan, which is an instrument aimed at controlling environmental changes and preventing housing developments or traffic-generating activities in areas which are already acoustically polluted. Each new intervention must be accompanied by a provisional rating of climate and noise impact, in order to verify the possible presence of exceeding noise immissions.
On the basis of the noise mapping the Municipality of Monza it has prepared the Action Plan, viewed and downloaded from the links below.

After fulfilling the compulsory phase of communication and consultation of citizens and stakeholders, the Action Plan was approved by the City Government by resolution no. 185 of 31/05/2016.

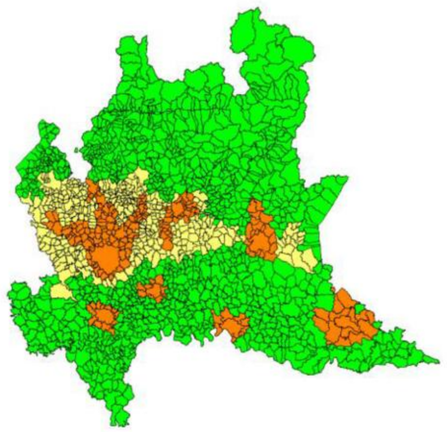
The Action Plan has identified measures to be implemented in the short, medium and long period which are not only directly focused on the acoustic phenomenon, but are also strategically related to urban planning, mobility, traffic, activities aimed at informing the public etc., which imply a potential reduction of noise emissions coming from road sources related to municipal infrastructure. Among short term maesures, which coincide with LIFE MONZA project lifetime, two specific interventions will be implemented in the pilot area:

1. the creation of a restricted traffic area for all trucks;
2. the implementation of a 30 km/h.area.

Legal tools

Type of Law	No. of law	Subject	Short summary
EC Directive	2008/50	On ambient air quality and cleaner air for Europe	It sets standards and target dates for reducing concentrations of fine particles, which together with coarser particles known as PM10 already subject to legislation, are among the most dangerous pollutants for human health.
Legislative Decree	13.08.2010 n. 155 as integrated and modified with Legislative Decree 24.12.2012 n. 250	Attuation of EC Directive no. 2008/50 on ambient air quality and cleaner air for Europe	It sets a legal unitary framework concerning air quality evaluation and management aimed at identifying air quality standards in order to prevent or reduce harmful effects for human health and environment
Regional Law	24/2006	Prevention and reduction of emission in the atmosphere to protect health and environment	It is aimed at enforcing regional commitment for the implementation of a framework of planning and coordination of lines of action for the achievement of air quality levels established by the EC to protect health and the environment, through the reduction of in relation to weather and climatic conditions of the basin.
Resolution of Regional Government	2605/2011	Division in areas and agglomeration of regional territory for evaluation of air and environmental quality	Thanks to this resolution, the regional territory is divided in areas and agglomerations in order to evaluate air and environmental quality
Resolution of Regional Government	593/2013	Approval of Regional Plan of interventions for air quality	The Plan offers a synthesis of knowledge on the different types of air pollutants and weather-climatic characteristics influencing their spread, in order to support future emission regulation policy.
Resolution of Regional Government	2578/2014	Implementation of Regional Plan for Air Quality	The resolution approves measures aimed at limiting circulation to all or some categories of vehicles in the different areas of Lombardia according to the exceeding in limit values
Resolution of Regional Government	5656/2016		Protocol to implement temporary measures at local level by adhering Municipalities in case of continued exceeding of limit values of fine particles (PM10)

LOMBARDIA REGION



Legenda

Area 1 – agglomerations plus Pavia, Cremona, Lodi and Mantova and their surroundings (209 cities)

Area 2 – Plain area with high urbanization excluded Pavia, Cremona, Lodi, Mantova and surroundings

Figure A1.01 Source: Regione Lombardia website
Link:http://www.regione.lombardia.it/cs/Satellite?c=Redazionale_P&childpagename=Ambiente%2FDetail&cid=1213374630533&pagename=MBNTWrapper

EUROPEAN AND REGIONAL LEGAL FRAMEWORK ABOUT ENVIRONMENTAL POLLUTION

A low emission zone (LEZ) is a measure to meet air quality obligations, improve environmental quality and lower traffic-related health risks in their cities. Many European cities have introduced low emission zones (LEZ) to improve air quality and to meet the limit values. There is increasing evidence that LEZs can have significant benefits to human health, even though the reduction of PM10 levels may be modest. There are no uniform regulations or standards for LEZs in the Member States, although a few (Germany, Denmark, Sweden, Netherlands, Czech Republic) have adopted national LEZ regulations. Even within the Member States with national LEZ regulations, each city may be free to implement LEZ with local conditions and administration, creating a patchwork of restrictions and procedures that can be a burden for intercity and international drivers and road transport operators. Many cities have introduced mobility and transport measures which have led to the reduction of air and noise pollution. Some cities have adopted innovative approaches and technology in their implementations of LEZ, in order to solve environmental problems and contribute to effective urban mobility and economic growth, which are among the objectives of the Europe 2020 strategy.

Italian Government has transposed in our legal framework the contents of EC Directive 2008/50 setting a unitary framework air quality evaluation and management aimed at identifying air quality standards in order to prevent or reduce harmful effects for human health and environment.

Although Italy has no national LEZ framework, several regions in Italy have coordinated LEZ within their regions, including Valle d'Aosta, Bolzano, Emilia Romagna and Lombardia.

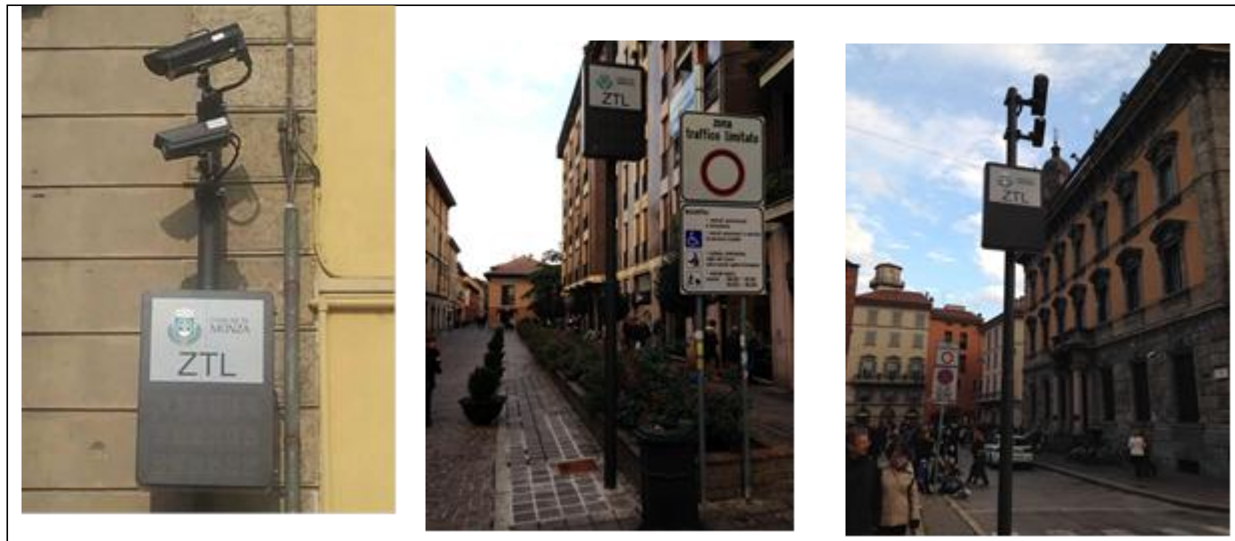
More specifically, Lombardia has developed an extensive legislation on the topic, seemingly because of environmental pollution problems that arise from the internal geographical location and the large flat area that prevents air exchange.

Generally speaking, the regional territory has been divided in areas and agglomerations in order to evaluate air and environmental quality. When pollutant emissions limit values are exceeded, measures are taken aimed at reducing air pollution, as well as blocks of circulation for all or for certain categories of vehicles or reduction of temperature of heating in buildings. According to the exceeding in values, it is decided if measures are applied to the larger Area 2 or to the smaller Area 1.

In 2016, Municipalities have signed a Protocol aimed at implementing temporary measures structured on two levels to be activated at local level in case of continued exceeding of limit values of fine particles (PM10) for at least seven days in the concentrations of n, respectively. 50 and 70 micrograms / cubic meter of PM10.

Legal tools

Type of Law	No. of law	Subject	Short summary
Legislative Decree	n. 285/1992	Street Code	It rules road traffic in general and allows Municipalities to define pedestrian and limited traffic zones according to traffic effects on health, safety of circulation, public order and environmental and cultural heritage
Decree of President of Republic	250//1999	Rules for authorizing the installation and operation of systems for the detection of accesses of vehicles to city centre and RTZ	Municipalities willing to operate systems aimed at detecting vehicles accessing the City Centre have to ask for authorization to the Ministry of Public Works. Systems have to be omologated according to UNI 10772
Resolution of City Government	180/2014 270/2014	New structure of RTZ Approval of rules to access the RTZ	With this resolution the City Government has identified the boundaries of the RTZ With this resolution the City Government has identified the different categories which are authorized to access the RTZ and the procedures for granting authorizations
Order of the Mayor	N.A.	Each year the Mayor of the Municipality defines rules to access the RTZ	The yearly order of the Mayor defines schedules, duration of the limitations and exceptions to the prohibition of access



License plate recognition system in Monza to prevent access in Restricted Traffic Area

Figure A1.02
Source: Ufficio Mobilità e Trasporti Comune di Monza

LEGAL FRAMEWORK AT NATIONAL AND LOCAL LEVEL ABOUT RESTRICTED TRAFFIC ZONES

License plate recognition system is becoming more and more popular and has been already applied in a number of LEZs. It operates on the basis of cameras installed at the LEZ entry points and that can also be scattered inside territory of LEZ. The cameras are scanning the license plate number of vehicles entering the LEZ and comparing it with the list of vehicles uploaded on the database. In the case the common EU database is developed, the license plate based access would also allow to easily apply the system to foreign vehicles.

Currently license plate system has been successfully operating in London, Milan and other LEZs. For example, in case of London LEZ cameras read number plate as a vehicle drives within the LEZ and check it against the database of registered vehicles. In Monza a system operating with cameras scanning the license plate number of vehicles entering the Restricted Traffic Zone (RTZ) in the historical centre of the city has been implemented and activated in April 2014.

A1.2 Operational Context: Noise Monitoring Systems

Standard and smart low-cost noise monitoring systems

Operational context: Standard Noise Monitoring Systems

The need of measurements in the field of environmental noise has led to develop a technical standardization upon devices, usually employed in monitoring systems too, whose architecture depends on the kind of source under investigation as well as the measurement time requested. Generally, two types of noise monitoring are considered:

- Short-time measurements (spot), by means of sound level meters;
- Long-term monitoring, carried out with fixed station consisting of cabinet, power supply and sound level meter.

The microphone is the transducer that transforms the mechanical pressure into electrical signals. In the field of metrology, condenser microphones are commonly used: these devices are based on the voltage variation at the terminals of a capacitor having one of the two armatures fixed and the other is constituted by the microphone membrane itself, both provided with a certain amount of charge electricity. Being constant the charge, the variations of the distance between the plates due to the vibration of the membrane cause a variation in the electrical voltage across the capacitor. The so-called "*electret microphones*" is provided with a dielectric material keeping inside the electrical charge and therefore the microphone does not need to be powered.
The basic characteristics of a microphone are the following:

- sensitivity: electric voltage in mV generated by 1 Pa sound pressure level;
- dynamic: the difference between the maximum sound pressure level and equivalent level of background noise;
- sensitivity variation with frequency (bandwidth);
- sensitivity variation with the angle of incidence: there are microphones having a linear frequency response in free field conditions and others with the same characteristics for diffused field conditions.

The sound level meters allow processing the electric signals generated by the microphone, in order to obtain the numerical values of the typical descriptors used in the field of environmental noise. The sound level meters basically work as follows:

- frequency weighting
- calculation of the Root Mean Square (RMS) value;
- time weighting of the RMS value by means of one of the exponential time constant (i.e. Fast, Slow, Impulse)
- time averaged RMS value for the calculation of the equivalent sound pressure level Leq.

Nowadays, in the field of sound level meter specifications, the most technical important reference is given by standard IEC 61672 that provides tolerance limits for the frequency response of the devices, self-generated noise and linearity.
Two main classes of precision instruments, and related sets of specifications, are defined:

- Class I: maximum linearity error of ±1.1 dB for around 1 kHz and linear operating range shall be at least 60 dB and linear amplitude deviations shall not exceed ±0,6 dB.
- Class II: maximum linearity error of ±1.4 dB for around 1 kHz and linear operating range shall be at least 60 dB and linear amplitude deviations shall not exceed ±0,8 dB.

Class I (Precision) must be employed for accurate sound measurements in laboratory and in field, while Class II (General Purpose) could be used for general measurements in field.

Operational context: Smart Low-Cost Noise Monitoring Systems experiences and procedures

The increasing availability of low cost computing devices, microphones and wireless connectivity allows the capability to define a system able to detect, analyze and streaming noise data, giving the possibility to develop different kinds of systems, having smart and low-cost characteristics.
Smart low-cost noise monitoring systems allow a widespread and continuous noise monitoring, defining, in an adequate territorial scale, as urban areas, a network able to ensure a high quality output measurement data.
It is possible to classify the systems according to different characteristics, as network typology, data transmission procedures, microphones, etc. There are sensor networks microcontroller based, as many of the common noise monitoring systems complaint to Class I IEC 61672 standard and, also, there are networks embedded pc based, consisting of low cost mini pc, equipped with a sound board, with Wi-Fi capabilities (or GPRS/3G/4G), and a signal analysis software able to process data from the sound data, using low cost microphone, as MEMS.
Focusing on types of microphones and their development during the years, becoming high performing and available at low cost, it's possible to consider the prepolarized condenser microphones (electret microphone), which have been developed since 1960's, and MEMS (Micro Electro-Mechanical Systems) microphones, introduced at the beginning of the year 2000. Both are accessible as low-cost productions and they could be applied according to standard IEC 61672 requirements, in Class I or Class II, depending on devices' technical specifications. There is still not a wide employment of MEMS in outdoor measurements, particularly for their lack of stability over the time, due to the deteriorative effects of weather conditions. There is a growing interest towards these kinds of devices, since MEMS performance seems to be competitive compared to microphones used in Class I instruments, under certain conditions, especially for very low noise levels. Sensors characterized by more and better features are continuously developing, whereas the old ones become obsolete in a very short period.
Experiences about smart low-cost noise monitoring systems, carried out in Europe, are presented in following data sheets, focusing on procedures, technical characteristics, microphones specifications, pilot areas where the system has been implemented, noise indicators used and results.
A brief mention is dedicated to *participatory monitoring projects*, related to the collection and sharing of data, in order to allow the public participation and to increase the awareness about environmental issues.

DREAMSys

Table 1

Noise Monitoring System- DREAMSys Source: R.John T.Bunyan, DREAMSys MEMS Microphone specifications.2007	
MEMS microphones specification	
Acoustic dynamic range	70 dB
Minimum detectable sound pressure level	40 dB(A) could be workable 30 dB(A) would be useful 20 dB(A) would be ideal
Maximum detectable sound pressure level	110 dB(A)
Acoustic frequency range	20 Hz to 20 kHz
Mechanical membrane resonant frequency	> 30 kHz
On-chip temperature measurement accuracy	< 1 °C
Operating voltage	3.3 V
Operating current	few mA
Analogue voltage range	≈ 1 V
Size of PCB assembly	10mm < x <10 mm
Shape of PCB	Optimized to avoid diffraction effects
User defined period setting	10 min
Indicators (equivalent level)	*LAeq, LCeq, LA10, LA50, LA90*
Others:	waterproof cover battery powered (run for more than two weeks)

Description

DREAMSys (Distributed Remote Environmental Array & Monitoring System) is a project to develop a new environmental noise monitoring system and mapping using new kind of sensors. It is a project involving research and technology organizations, manufacturers and environmental noise experts, sponsored by the Technology Strategy Board, established by the British Government and developed by an industrial group led by NPL (National Physical Laboratory).

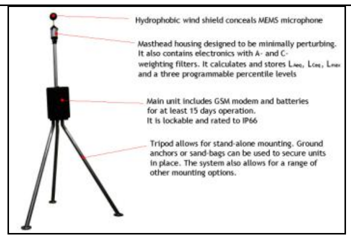
In order to give a contribution to the implementation of Directive 2002/49/EC, particularly on noise mapping process, an array of low-cost environmental noise monitoring units, using wireless transmission of measured data has been developed and tested. Monitoring data can be used for noise mapping, using bespoke developed software. A key point of the process is the use of low cost MEMS microphones (Micro-Electro-Mechanical Systems), which allow a large number of monitoring stations working simultaneously. The considerable growth of portable electronic consumer products such as mobile phones and notebook computers has stimulated the development of MEMS microphones in the last years. The project, started in 2007 and concluded in 2010, developed a system which has been tested in laboratory and in situ measurements.

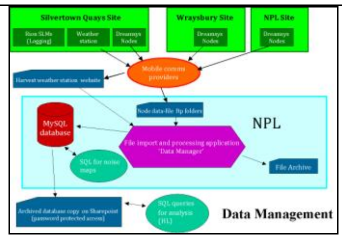
The specifications for MEMS microphones are shown in Table 1. The prototype and the architecture of the system are shown in the following Figures 1-2. At the aims to assess the distributed measurement approach, four test sites have been identified. The site at NPL was the first case study to evaluate the performance of the new equipment: part of the site is located close to a busy road, other are near a park and sports fields and it is in the take-off flight path of Heathrow airport. Seven units have been deployed, investigating mounting configurations, calibration and monitoring of reliability. A comparison between industry standard equipment based on type 1 sound level meter and DREAMSys monitoring system has been also made. The following Figures 3-4 show DREAMSys measurements instrument deployed at the NPL site and measurements instruments mounting solutions at Wraysbury Reservoir.

Another location is Wraysbury Reservoir (Staines, UK), close to Heathrow airport and a major motorway, with a high degree of exposure to weather, presence of wildlife. The Figure 3 display some of the installations used, including one unit mounted to a boat. The monitoring system considered 6 units deployed at Wraysbury for a period of 3 weeks in June 2009.

Distributed noise measurements at Festival Square in Edinburgh were carried out to study the relationship between sound perception and the physical level of noise. Measurements were carried out over 3 consecutive days in October 2009, with the instrumentation being removed from the square overnight, consisting of 8 units, 6 around the boundaries and two in the square.

The fourth area was Silvertown Quays, no public access area, located in the direct take-off path of London City airport and, despite this, the area is selected for residential development. It is also close to the Docklands Light Railway, a major road with the presence of commercial activities. Using the tripod arrangement, 39 units have been deployed at the area.





Figures 1-2 - On the left, prototype and on the right, the system architecture.
Source: http://projects.npl.co.uk/dreamsys/

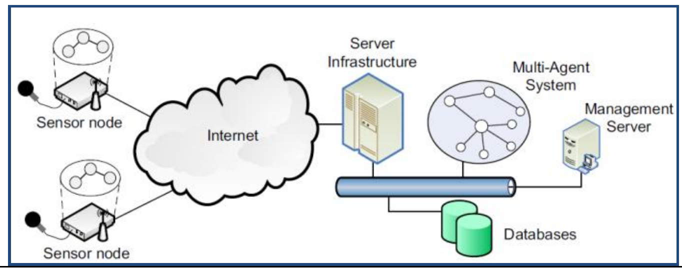
Figures 3-4 – On the left, DREAMSys measurements instrument deployed at the NPL site and, on the right, measurements instruments mounting solutions at Wraysbury Reservoir.
Source: Richard Barham, Martin Chan, Matthew Cand. Practical experience in noise mapping with a MEMS microphone based distributed noise measurement system; Proceedings: Internoise 2010, City of Lisbon, Portugal, 13th -16th June 2010.

Smart monitoring networks – Ghent University

Table 1

Sensors nodes technical specifications.
Based on information available on: B. De Coensel, D. Botteldooren. Smart sound monitoring for sound event detection and characterization. In Proceedings of the 43rd International Congress and Exposition on Noise Control Engineering (Inter-Noise), Melbourne, Australia (2014).

Sensors nodes technical specifications	
Short /long term noise measurement	long term noise measurement
Embedded pc monitoring system /Units with microcontroller and digital signal processor	embedded pc monitoring system
Temporal resolution	125 ms
Acoustic indicators	$L_{Aeq,15\ minutes;}$ L_{A90}, L_{A50}, L_{A10}, $L_{A01;}$ the number of sound events (M_{60}, M_{70}, $N_{cn)}$ indicators for the temporal structure of the sound, psychoacoustic indicators (loudness, sharpness), spectral indicators as the centre of gravity of the average 15-minute spectrum, the presence of tonal components and aggregate indicators.
Spectral data	1/3 octave
Others	
Weatherproof	weatherproof box
Connectivity	connected to internet - *plug-and-measure* approach
Possibility of audio recording	fragments of audio recording
Pilot area of implementation	
Urban/suburban	urban
Territorial scales	1,18 km^2
Number of sensor nodes	12



Figures 1-2 - On the left, prototype and on the right, the system architecture.

Source: B. De Coensel, D. Botteldooren. Smart sound monitoring for sound event detection and characterization. In Proceedings of the 43rd International Congress and Exposition on Noise Control Engineering (Inter-Noise), Melbourne, Australia (2014).

Description

The research Group Waves (wireless, acoustics, environment and expert systems) of Ghent University, is working on smart monitoring networks and its competences are focused on the following activities: application of models for machine listening and auditory cognition into smart sound meters and acoustic sensor networks; deployment of large-scale networks of sound monitoring stations in Ghent, Antwerp, Brussels, Rotterdam and Paris; mobile sound measurements combining GPS data allow to map larger areas with fine spatial resolution; development of dynamic noise mapping techniques. Many research projects have been undertaken and a spin-off company for the development of smart sensor network solution has been created. Noise smart monitoring systems are employed for noise measurements, allowing the calculation of the main noise parameters, for soundscape analysis, for sound recognition, for source localization, for noise mapping, in fixed and also dynamic configuration.

A smart sound monitoring project has been carried out in the Rotterdam harbor zone, in 2013, focused on sound events detection and characterization. A measurement campaign using 12 noise smart measurement devices has been started, jointly with an online survey on sound events and sleep quality. Low-cost computing devices and microphones, jointly with wireless transmission, allow the possibility to use a large number of monitoring stations to be deployed in urban area, defining a well structured and dense network, able to give more details about the noise sources and events. Also, the acoustic characterization of the local area allows a more effective identification of the noise policy to be undertaken. The project carried out in Rotterdam aims to study an effective combination of objective measures and subjective perception, expressed by people in an online survey, in order to detect sound events and to estimate the impact on well-being and health. The area, 1,18 km^2, is located in Rotterdam harbor zone, with about 4.500 inhabitants. Focused on monitoring approach adopted, it was based on 12 cost-effective sensor nodes, placed on the façades of the buildings on voluntary basis. Sensor nodes are composed of a single board computer, equipped with a CF card, a sound card, an ethernet card and a microphone, inside a weatherproof box. Sensor nodes could be adopted and used by inhabitants of the area. The sensor nodes are plug-and-measure, that is the device is directly connected to the internet and the sensor has no buttons nor display (Figure 1). If plugged in, the sensors nose start and continue to measure 1/3 octave band levels, with a temporal resolution of 125 ms. The levels were sent to the server infrastructure, in Ghent, to be processed. Sensors have also the possibility to record and transmit short audio contributions and to save data internally. Data were processed and managed and the results stored in a warehouse database (Figure 2). The acoustic parameters, calculated on a 15 minutes basis are LAeq,15 minutes and the standard deviation of the level, percentile levels (LA90, LA50, LA10, LA01), the number of sound events, indicators for the temporal structure of the sound, psychoacoustic indicators (loudness, sharpness), spectral indicators as the centre of gravity of the average 15-minute spectrum, the presence of tonal components and aggregate indicators. Sound recognition process is also developed and tested. The indicators M60 and M70 count the number of times that the A-weighted instantaneous sound level exceeds the threshold values of, respectively, 60 dB(A) and 70 dB(A), whereas the indicator Ncn counts the number of times that the A-weighted instantaneous sound level exceeds LA50 with at least 3 dB for at least, 3 seconds, in order to detect sound events from background level.

The long-term distributed approach, using 12 sensor nodes, allows analyzing the area, continuously and in real time conditions, giving the opportunity to investigate in detail the acoustic characterization of the area. In Table 2 the sensors nodes technical specifications are summarized.

The research group has also developed an approach for dynamic noise mapping relies on a sound source emission and propagation model. A method for calculating dynamic noise maps using fixed and mobile sound measurements has been developed and tested. The increasing availability of low-cost devices has led to the use of distributed sound measurement networks that can be applied to create dynamic real-time noise mapping, in order to validate the accuracy of traditional monitoring systems. Moreover, acoustic sensors networks allow to improve the spatial and temporal accuracy of the calculations. Both fixed and mobile sound measurements extend the spatial resolution of noise mapping, as mobile ones allow to complete the study area allowing a better characterization of the spatial distribution of the sound sources.

SENSEable Pisa

Table 1

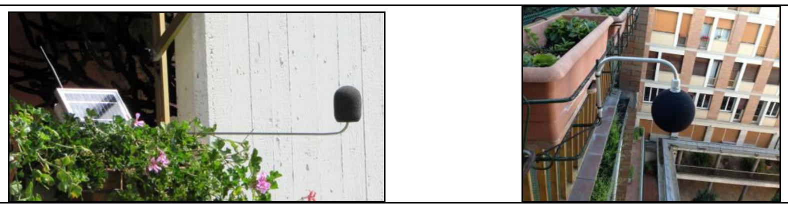
Noise Monitoring System - **SENSEable Pisa**
Source: based on information available on: Luca Nencini, Paolo De Rosa, Elena Ascari, Bruna Vinci, Natalia Alexeeva. *SENSEable Pisa: a wireless sensor network for real-time noise mapping*. Proc. Euronoise - Prague 2012.

Noise sensors characteristics	
Dynamic range	70 dB (A)
Time basis acquisition	1 sec
Microphone	¼-inch low cost microphones
Wireless transmission system	“ZigBee” transmission protocol
Digital filters	Low-high-band pass, A-ponderation
Event detection	Yes
Indicators (equivalent level)	LAeq. Lden, Lnight
Others:	waterproof cover weather data based on five minutes periods

Table 2

SENSEable Pisa output data. Day and Night mean noise levels for the first five sensors during the months of June and July 2011 and comparison with data of the strategic noise mapping of the city published on the website of SIRA.
Source: Luca Nencini, Paolo De Rosa, Elena Ascari, Bruna Vinci, Natalia Alexeeva. *SENSEable Pisa: a wireless sensor network for real-time noise mapping*. Proc. Euronoise - Prague 2012.

Sensor	Lden Sense	Lden Sira	Lnight Sense	Lnight Sira
1	70.2	70.1	62.2	61.3
2	64.8	66.1	56.6	56.1
3	65.6	65.9	57.7	56.1
4	68.8	65.8	60.8	56.8
5	79.7	60.5	74.1	51.0



Figures 1-2: On the left, Zigbee transmitter with a solar panel and a microphone installed on a balcony (2011). Source: Luca Nencini, Paolo De Rosa, Elena Ascari, Bruna Vinci, Natalia Alexeeva. *SENSEable Pisa: a wireless sensor network for real-time noise mapping. Proc. Euronoise* - Prague 2012.On the right, microphone of a monitoring station for anthropic noise assessment. Source: Luca Nencini, Bruna Vinci, Maria Angela Vigotti. Setup della rete Senseable Pisa per la realizzazione di uno studio di valutazione degli effetti del rumore antropico sulla salute dei cittadini. Proc. 41° Convegno Nazionale Associazione Italiana di Acustica. Pisa, 17-19 giugno 2014

Description

In order to promote citizens' participation in noise policy as requested in European directive 2002/49/EC, in the city of Pisa an experimental monitoring system for noise mapping was created, called SENSEable Pisa. It has been launched by a non-profit organization called *DustLab*.
The pilot project aims at developing a sensor network prototype in Pisa, based on *Real Time City* concept, for the collection and analysis of data to be used in urban planning processes.
SENSEable Pisa started in January 2011 and the system uses low cost wireless prototype noise sensors, based on a reuse of electronics of the old personal computers installed in the house of citizens (Figure 1), with the aim of sharing noise measures in a virtual community.
Noise levels measured in building facade are shown in real time in the website of the project and also on Facebook and Twitter social networks to inform participants and the followers of the project, whilst all historical noise data are collected in a central remote server.
Eight sensors were installed at houses of volunteer citizens to register noise in different areas of Pisa and send the data to the central server.
A first new aspect of the project has consisted of an application of a sensor network technology in order to provide reliable low cost measurements in real time, with high spatial sampling and without any need for wiring. So the resulting monitoring system has got superior characteristics in comparison with conventional monitoring stations.
It is possible to install more sensors for the detection of physical agents on the same transmission platform and also detect data regarding different pollutants.
The system structured in this way allows to:

- verify noise emissions from temporary events (project sites, shows, etc.);
- evaluate the long-term effects related to the adoption of new noise reduction technologies (electric cars, sound-absorbing asphalt and facades, etc.);
- real time monitoring of sensitive receptors (schools, hospitals);
- timely act on noise issues from the competent authorities.

The characteristic of noise sensors are reported in Table 1.
Moreover the system allows to involve citizens both using social networks, as a tool for dissemination of the project, and gathering feedback and comments on critical issues relating to noise in the city even for the positioning of the of wireless detection station. This design method, called *crowdsourcing*, could give a contribution to the implementation of the Directive 2002/49/EC, related to the assessment and management of environmental noise, about the requirement concerning the participation and the involvement of citizens to the noise action plan process.
The Table 2 shows how the data from SENSEable Pisa (columns "*Sense"*) are fully comparable with data of the strategic noise mapping of the city published on the website of SIRA (columns *"Sira"*), the regional institutional information platform of noise mapping data. The differences are due to the morphology or to anthropic noise of the urban areas.
Subsequently, the SENSEable network has been applied in a study on evaluation of anthropic noise effects on health citizens, in historical entre of Pisa. Homogeneous acoustic urban areas have been identified and six stations have been located in citizens’ buildings.

LIFE DYNAMAP

Table 1

Monitoring systems specifications	
based on information available on: X. Sevillano, J.C. Socorò, F.Alìas, P. Bellucci, L. Peruzzi, S. Radaelli, P. Coppi, L. Nencini, A. Cerniglia, A. Bisceglie, R. Benocci, G. Zambon. DYNAMAP- Development of low cost sensors network for real time noise mapping. Noise Mapp.2016; 3:172-189; L. Nencini, J.C. Socoró – *Dynamap project: hardware specifications update.* TecniAcustica, Valencia 21-23 Ottobre 2015; L.Nencini *Dynamap monitoring network hardware development.* Proceedings 22nd International Conference ICSV 2015, Firenze 12-16 Luglio 2015	
Monitoring system characteristics	
short /long term noise measurement	long term noise measurement
Monitoring network typology	Prototypal smart low-cost sensor networks
Broadband linearity range	40-100 dB(A)
Working range	35-115 dB
Noise indicator	Leq(A), 1 second time base
Spectral data	1/3 octave
Others	
Internal circular backup data storage of calculated data	
VPN connection	
Possibility of audio recording	
GPRS/3G/WiFi connection	
Periodic calibration, with respect to frequencies to be defined	
Pilot area of implementation	
Urban/suburban	two pilot areas, in urban and suburban environment
Territorial scales	from medium to large territorial scales

DYNAMAP (*Developing of low cost sensors networks for real time noise mapping*) is a LIFE+ project aimed at developing a dynamic noise map able to represent in real time the noise impact of road infrastructure. The main objective is to facilitate and reduce the cost of the updates of noise maps, as required by the European Directive 2002/49/EC. In order to achieve this purpose, an automatic monitoring system, based on high-quality and low-cost sensors and a software tool implemented on a general purpose GIS platform, will be developed and applied in two pilot areas located at the large ring road of Rome and in the agglomeration of Milan. The project is started in 2014 and it will be concluded in 2019.

Further objectives of the project are related to the demonstration that the dynamic mapping process is able to ensure a significant reduction in the resources needed to update noise maps, in time, costs and dedicated personnel; to the improvement of public information, providing different system access levels and also to the availability to provide additional information about meteorological conditions and other environmental topics, as air quality.

DYNAMAP system will be tested in two pilot areas, as examples of zones belonging to an agglomeration and to a major road infrastructure, as defined by END. The first pilot area is a significant part of the city of Milan, located in North of Italy, including many complex urban scenarios, and the second pilot area is located in Rome (Figures 1-2), along the ring road A90, a major road surrounding the roman agglomeration.

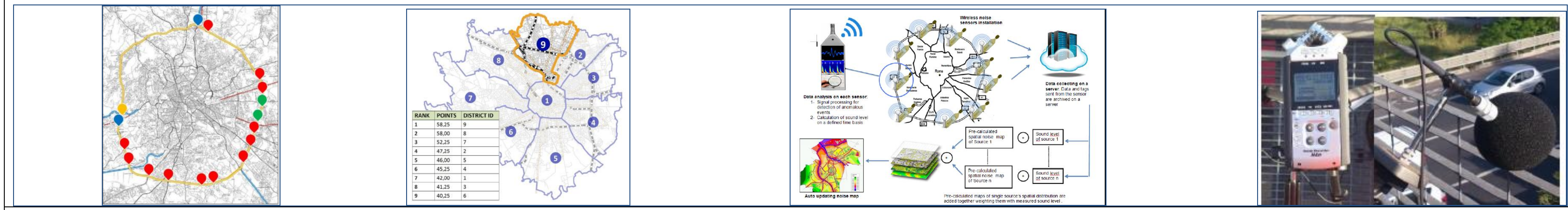
The system will be composed by low-cost sensors measuring the sound pressure levels emitted by the noise sources and of a software tool based on a GIS platform for real-time noise maps updating. A method for the identification of anomalous noise other than traffic noise (ANED) will be also developed.

The functional scheme (Figure3) consists of monitoring stations detecting the noise levels and hosting the ANED algorithm, able to remove anomalous events. The stations will provide a classified output with a time frequency of one second. Data will be sent to a central server, using wireless data communication as GPRS or 3G, to be analyzed, processed and used for noise maps.

Environmental noise monitoring campaigns have been conducted in May 2015 in pilot areas, implementing two demonstrative versions of systems, in order to acquire representative data about traffic conditions and to test ANED algorithm. The measures have been carried out using a low cost sensor developed by Bluewave (Figure 4) and a standard Class I sound level meter (Bruel & Kjaer 2250), with the intention of validating the output data of low cost sensor.

The prototype of the sensors network uses embedded computers, allowing remote access for running proper audio processing scripts and also, they permit to process data on sensor board, using the ANED algorithm, sending to the central server selected in advance and most accurate information.

A set of basic specification for monitoring station has been defined and reported in Table 1. Noise monitoring stations will be subjected to a periodic calibration, analyzing the changes of frequency response during the years. It is also provided to periodically store the minimum narrow band spectrum, referred to day period, in order to assess the values, and their changes in time, of the electrical noise level of the measuring chain.



Figures 1-2-3-4 - Starting from the left, pilot area in Rome, along the ring road A90 and critical areas highlighted in different colours. Then the pilot area in Milan and outcomes of the selection process. The functional scheme of DYNAMAP system and, on the right, the low cost measuring device used for noise monitoring campaigns.
Source: X. Sevillano, J.C. Socorò, F.Alìas, P. Bellucci, L. Peruzzi, S. Radaelli, P. Coppi, L. Nencini, A. Cerniglia, A. Bisceglie, R. Benocci, G. Zambon. DYNAMAP- Development of low cost sensors network for real time noise mapping. Noise Mapp.2016; 3:172-189.

BARCELONA- Noise Smart Monitoring System

Table 1

Noise Monitoring System **BARCELONA:** *Mixed smart low-cost and Class I sensors networks*	
Low-cost sensor specification	
Type approval	-
Integration time	1-15 minutes
Acoustic indicators	LAeq
Tolerance	LAeq ±2 dB(A)
Measure range	40-100 dB(A)
Calibration and verification	Verification of the calibration of the sensor must be able to be undertaken in situ using an acoustic calibrator which fulfills the requisites established under IEC 60942
Others	Weatherproof LAN/3G connectivity
Class I sensor specification	
Type approval	CEI-61672 Class I certification
Acoustic dynamic range	23-137 dB(A)
acoustic frequency range	10 Hz – 20kHz
tolerance	CEI-61672 Class I
acoustic indicators	LAeq; LCeq; LZeq; LAIeq; LAFMAX; 1/3 octave spectrum;
calibration of microphones	Verification of the calibration of the sensor must be able to be undertaken in situ using an acoustic calibrator which fulfills the requisites established under IEC 60942
Others	weatherproof WiFi/GPRS//3G Audio recording

Description

Over the past few years Barcelona has been working hard to be one of the smartest cities in the world and is promoting the use of innovative solutions to manage its services and resources to improve its citizens' quality of life. The municipality started to build up a noise monitoring network of Class I sound level meters in 2006 and, in order to increase the number of measuring points, in 2012 started to use noise sensors. One of the Smart City projects is the strategic deployment of *Sentilo*, a sensor data management and a platform that allows the city to become smart, efficient and to improve the environmental sustainability. *Sentilo* system is designed to create a link among sensors, actuators and the applications to manage urban services. Barcelona Noise Monitoring network is made up of a main network of class I sound level meters and a complementary sound sensors network. The network (Figure 1) is structured into two independent networks that communicate in different level: main and complementary noise control networks. The main difference between them is the quality of the measures in terms of characteristics and costs and the final uses are also different.

The main network consists of Class I 25 noise monitors, in fixed and mobile measuring points, and will have 31 in the future. The main objectives of the network are to estimate noise levels in critical areas, to evaluate the noise reduction due to the implementation of noise action plans, to update the noise map and to identify noise sources. The noise monitors technical characteristics are reported in Table 1.

The development of the complementary sound sensor network started in 2012. Sound sensors were installed in two construction work areas and the quality of the measures of two kinds of low- cost sensors was tested, with not positive results. In 2014 the Noise Control Department defined the minimum technical specifications of the sound sensors (Table 1) and a control system able to validate the quality of the sound measurements before the installation of the sensors in urban areas has been carried out. The aim of this low-cost monitoring network, initially formed by 11 sensors and integrated in *Sentilo* platform, is to increase the number of measuring points in order to take over the environmental noise changes. Concerning the data transmission, two different protocols, one for the main Class I sound level meters network and the other for the low-cost complementary network, have been designed. About the main network, in order to unify the data management as well send information, all the providers uses the same template file (.csv) created by the Noise Department of the Barcelona City Council. The data have been stored, on a daily basis, in an FTP server and are loaded in the COGNOS system (Figure 2). The user can input extra-data to the system by the Data Entry platform. The complementary sound-sensors network is a part of the City Sensors Network which uses *Sentilo* as the platform able to link sensors and actuators and to manage urban application and services (Figure 3). *Sentilo* is a tool designed for cities that want to control the deployment of sensors and actuators in a centralized and common way. The platform is open source and has no licensing costs. Barcelona, in order to manage noise issues, uses two different reporting interfaces: IBM *Cognos Query Studio*, used to make a detailed data analysis, and a corporative platform called *Situation Room*, used to obtain an overall view of the city status in real time (Figure 4) as well as to integrate and share information about the city and its services. *Cognos Query Studio* allows the analysis of data coming from both noise monitoring networks, the main with Class I monitors and the complementary with sound sensors. The *Situation Room* platform permits only the management data of the sound sensors, but it also consents to link these data with information from other sources, allowing real time recognition.

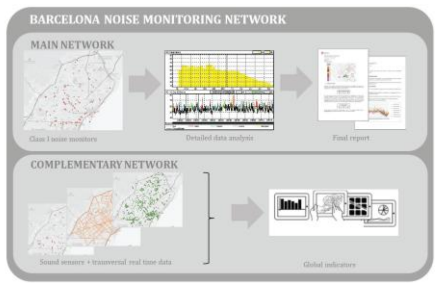
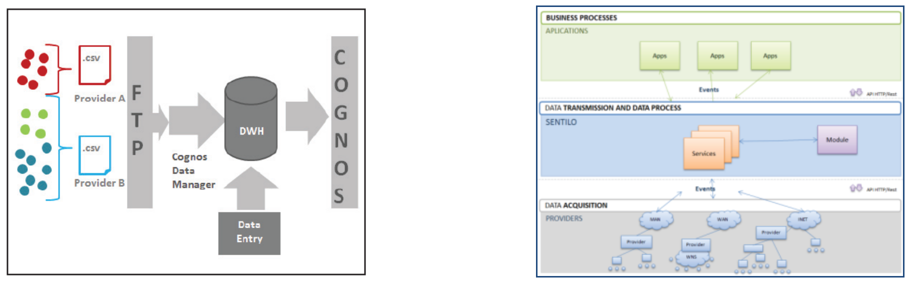


Figure 1 - Noise monitoring network basic structure.



Figures 2-3 - On the left, noise monitors data transmission for the main network. On the right, *Sentilo* structure.

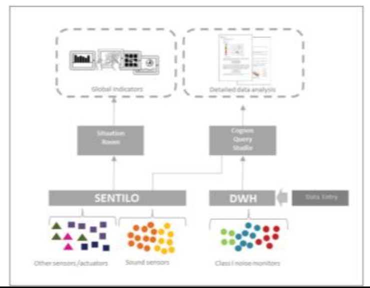


Figure 4 - Management and reporting interface.

Source: Júlia Camps Farrés, *Barcelona noise monitoring network*. EuroNoise 2015, 31 May - 3 June, Maastrich

Low-cost noise monitoring system based on smartphone devices - Regional Environmental Agency of Piedmont

Table 1

Noise Monitoring System **Low-cost noise monitoring system based on smartphone devices - Regional Environmental Agency of Piedmont**	
Android smartphones characteristics (*Noise Meter* app)	
Sampling frequency adjustable	8000, 11025, 22050, 44100, 48000 Hz
Gain	1 dB steps in the range -40 - +40 dB
Integration period	from 1 sec to 10 minutes;
Events detection	Yes
Digital filters	Low-high-band pass, A-ponderation
Indicators (equivalent level)	Peak, minimum, maximum, arithmetic average, energetic average
iOS smartphones characteristics (*Noise Immission Analyzer* app)	
Sampling frequency	44100 Hz
Calibration	With a known signal
Digital filter	A-B-C-linear ponderation, fast, slow
Indicators (equivalent level)	minimum, maximum, energetic average
audio file record	up to 20 seconds

Table 2

	LAeq Class 1sound level meter – LAeq smartphone dB(A)		
Reference Time	Day	Evening	Night
Minimum	-3.3	-1.9	-1.6
Average	-0.5	0.3	-0.1
Maximum	1.6	2.5	1.3
Standard deviation	0.8	0.7	0.5

Description

Many studies regard the use of smartphone, equipped with adequate instruments, as noise measurements tools, and there many mobile applications able to allow noise measurements through smartphones. Following the experiences carried out by the Regional Environmental Agency of Piedmont, which in order to study the accuracy of environmental noise measurements using smartphone and to investigate the possibility of using low-cost devices, has carried out two different types of tests, comparing output data of five different smartphones (Android and iOS) and a Class I sound level meter, in an anechoic room, and carrying out, for more than three months, a long term environmental noise monitoring, using a smarthphone and a Class I sound level meter. Then, a prototypal low-cost noise monitoring system based on smartphone devices has been developed and applied, in collaboration with the Municipality of Turin, in San Salvario area, in order to assess noise level caused by *movida* phenomenon. Considering the tests, the first one has been carried out in an anechoic room, comparing output data of different five smartphones and apps, relative to the response to white noise at different sound pressure levels. The noise meters developed based on Android are provided with the free application *Noise Meter* available on Google Play. The technical characteristics are reported in Table 1. Data can be saved in a text file and the frequency spectrum cannot be developed. The on-sale app *Noise Immission Analyzer* for iOS was used, but currently, it is no more available. It is not possible to save noise data in a text file nor to measure frequency levels (Table 1). The laboratory test was conducted comparing the response to white noise, at different values of SPL, by the smartphones and a Class 1 sound level meter and using different microphones, the internal microphone of the smartphones, the original headphone microphones and a MicW microphone, plugged into the smartphones. In Figure 1 the results obtained using the internal microphone of the smartphones. The results show equal responses of data coming from the five different smartphones, in the range 45-80 dB(A), with differences of 2-3 dB. The iOS phones result is under 1 dB difference up to 110 dB(A). Figure 2 shows the results using the original headphone microphones. In the range 60-80 dB(A) the responses are quite equal for all the devices, and in the 40-85 range there is a deviation of 2-3 dB) for the iOS and the Samsung Advance. In Figure 3 the results using a MicW microphone, plugged into the smartphones. The iOS show good results, compared to the output data using professional Class I sound level meter, in the range 40-110 dB(A), while HTC phone for the range 55-110 dB(A). An additional test for the evaluation of the frequency response, using Samsung Advance smartphone and measuring pure tones, in the range 50-10.000 Hz and with variable intensity, in comparison with a Class 1 sound level meter, has been carried on. The obtained data comparing the global equivalent noise levels, because *Noise Meter* does not allow the frequency spectrum, highlight good responses in the frequency range 160-5000 Hz, up to 80 dB(A) level. The second test, regarding road traffic monitoring, has been carried out for 100 days, using a Samsung Advance smartphone, with headphone microphone and a Class 1 sound level meter. The standard deviation of the differences between the two instruments is always smaller than 1 dB. In Table 2 the values of the average, the minimum, the maximum and the standard deviation of the differences, are shown. Data are based on 5-minute LAeq series, calculated for the monitoring period of 104 days. Based on these results, further experiences have been carried out, concerning a self-built low cost noise level meter, using digital MEMS microphones, and a self-built app for Android. The free and open application OpeNoise Meter, in Android environment, able to be used with smartphone and a low-cost noise device, has been developed. In figures 4 and 5 the hardware set-up for outdoor noise measurements, using smartphones.

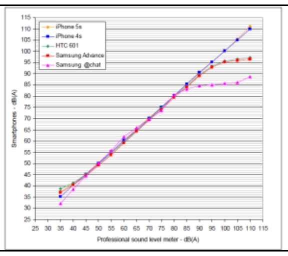


Figure 1 - comparison of results using the internal microphone of smartphones .

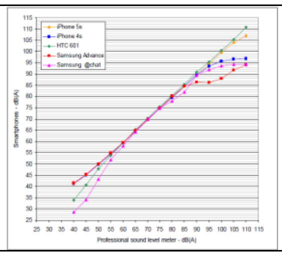


Figure 2 - comparison with the original headphones of the smartphones.

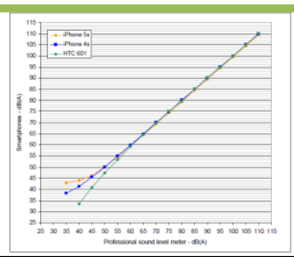


Figure 3 - comparison using the MicW microphone plugged into the smartphones.

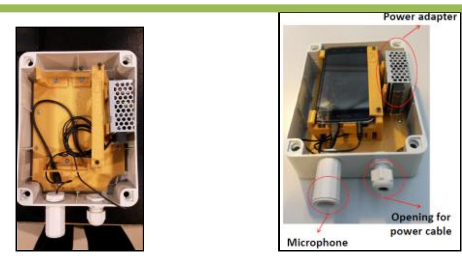


Figure 4 - Hardware set-up for outdoor noise measurements, using smartphones. .

Source: J. Fogola, S. Masera, V. Bevacqua. Smartphone as noise level meter? Proceedings 22nd International Conference ICSV 2015, Firenze 12-16 Luglio 2015

Source: J.Fogola, E. Gallo. Low cost leisure noise monitoring in the San Salvario area. Presentation available on: https://workinggroupnoise.files.wordpress.com/2016/06/fogola_low-costs-noise-monitoring.pdf

Participatory monitoring projects

NoiseWatch

The European Environment Agency (EEA) maintains the official data base related to strategic noise maps delivered in accordance with European Directive 2002/49/EC (Environmental Noise Directive END), related to the assessment and management of environmental noise. Additionally to this information, in the past few years, the need to make available most recent data about environmental noise, having different characteristics compared to official institutional data collected in accordance with END, has been highlighted. To this purpose, NoiseWatch Service, has started to be implemented by EEA in 2011, making available both noise information from official scientific sources, as measurement networks of European cities, and crowdsourced observations from citizens. The service, currently not updated, allowed people to submit observations on sound environment and rate the acoustic quality of the area and also to use mobile device application for iPhone and Android for mobile measurements, converted to a rating. The service was structured in different map layers, related to the various use and different kind of information: Citizen observations, containing ratings by users either via web app or mobile device app and Citizen rating aggregation, including aggregation of users' observations; Near real time noise measures, including unofficial near real time data from permanent official noise monitoring stations located in Dublin; Noise agglomeration - modeled data, yearly updated, for a number of European cities, concerning transport infrastructures and industries. NoiseWatch is an example of citizen-based information, useful for people involvement, for raising noise awareness, for availability of output data coming from different sources and users and adopting different protocols and procedures. One of the key output of the project is that, comparing ratings with END official data, the road traffic noise emerges as the most important noise source for both the data bases, whereas industrial noise, the source with least people exposure based on END data, results, based on ratings, the second important source after road transport .

Smart citizens project

The Smart Citizens project, developed by Fab Lab Barcelona at the Institute for Advanced Architecture of Catalonia, is a platform aimed to generate participatory processes of people in urban areas. This platform connects people with their environment and their city to create more effective and optimized relationships between resources, technology, communities, services and events in the urban environment. This purpose is achieved connecting data, people and know-how, based on geolocation, the Internet and free hardware and software for data collection and sharing. In particular, the Smart Citizen Kit is a piece of hardware comprised of a sensor and a data-processing board, a battery and an enclosure. The first board carries sensors that measure air composition (CO and NO2), temperature, humidity, light intensity and sound levels. Once it is set up, the device will stream data measured by the sensors over Wi-Fi using the FCC-certified, wireless module on the data-processing board. The device's low power consumption allows for placing it on balconies and windowsills. Power to the device can be provided by a solar panel and/or battery. The Kit is compatible with Arduino and all the design files are open-source (schematics and firmware).

CITI-SENSE

CITI-SENSE is a project co-funded by the European Union's Seventh Framework Programme for research, technological development and demonstration, started in 2012. The main aim of the project is to develop "citizens' observatories", in order to improve people involvement in environmental processes, developing sensor based Citizens' Observatory Community, for improving quality of life in the cities. The three pillars of the project are: technological platforms for distributed monitoring, information and communication technologies and people involvement. Three pilot case studies concerns the environmental issues related to combined environmental exposure and health associated with air quality, to noise and development of public spaces and to indoor air at schools. The projects in pilot areas have been designed in collaboration with citizens' groups and decisions have been based on data collected by people, using low-cost reliable microsensor packs. Citizens involved used a toolkit to collect objective information about some environmental conditions of the analyzed area and, and also they gave their personal perceptions. The toolkit, composed by tools for subjective and objective monitoring of environmental quality, consists of a Kestrel 4000 Pocket Weather Meter, a Sensor Data Storage, a Sense-It-Now app and a dedicated noise sensor and CityNoise app. Focus on noise, CityNoise is the application for android smartphone, able to provide sound pressure levels and detects sound events. A measurement protocol has been developed, defining the exact time to be dedicated to observe, measure, comment and take photos. A monitoring session takes time of about 15 minutes, measuring noise levels, wind speed, humidity and temperature, giving meantime a perception of the place and, at the end of the session, taking photos.

NoiseTube

NoiseTube is a research project, aims at proposing a participative approach for monitoring noise. It started in 2008 at the Sony Computer Science Lab in Paris and it is currently maintained by the Software Languages Lab at the Vrije Universiteit Brussel. The system allows the download of applications for mobile phones (iOS, Android, Java ME), able to turn phones into noise measurements instruments. Collected data could be uploaded to a server and shared, creating noise maps. NoiseTube software allows the A-weighted equivalent sound levels per second, for defined time intervals and, in order to ensure the accuracy of data, a calibration procedure must be implemented, according to sound pressure and frequency, for each smartphone model. The accuracy and precision, in different parts of the process, are continuously maintained and improved. The calibration process, for different mobile phones, is ensured, as the spatio-temporal density in noise maps drafting. Accuracy and comparison of noise maps based on participatory sensing data and official one are analyzed and many experiments have been carried out. An evaluation tool is also provided and NoiseTube can collect citizens' perceptions on sound environment through a questionnaire. A privacy-preserving system for participatory sensing, based on cryptographic techniques and distributed computations in the cloud, able to ensure security both to users and data management providers, has also been validate in the context of NoiseTube.

Prevalent requirements, advantages and limitations of smart low-cost monitoring networks

Table 1.
Smart low cost noise monitoring systems - main characteristics arising from analyzed projects

Smart low cost noise monitoring systems	
main characteristics arising from analyzed projects	
Short /long term noise measurement	long term noise measurement
Embedded pc monitoring system /Units with microcontroller and digital signal processor	Embedded pc monitoring system
Type of microphones	MEMS microphones ¼ - inch condenser low cost microphone
Time basis acquisition	Different values. In most frequent cases =1 sec;
Acoustic dynamic range	70 dB
Acoustic Measure range	Different ranges. 30 (40)-100 (110) dB(A)
Acoustic frequency range	20 Hz-20 kHz
Floor noise value	30-35 dB(A)
Tolerance	LAeq ±2 dB(A)
Acoustic indicators	In all cases studies: L_{Aeq}, L_{A10}, L_{A50}, L_{A90}; In some cases studies: $L_{A01;}$ L_{Ceq}, M_{60}, M_{70}, N_{cn}
Spectral data	1/3 octave
Calibration	Periodic calibration
additional characteristics	
weatherproof	Applied in all case studies
connectivity	WiFi/3G/4G
possibility of audio recording	Applied in some case studies
other properties	Extensible with temperature/humidity sensors, air pollution monitoring sensors, GPS logging etc; battery for energy storage.
Size of PCB assembly	10mm < x < 10 mm
Shape of PCB	Optimized to avoid diffraction effects
pilot area of implementation	
Urban/Suburban	Urban and sub-urban areas
Territorial scales	Different dimensions, from medium to large scale; (most frequent dimension in urban area: ≈1,00 km^2)
Number of stations	Different situations. For areas of medium spatial dimensions, in most cases, from 5 to 20 units

The analyzed projects highlight strengthens and weaknesses of smart low-cost noise monitoring adoption. The availability and the continuous development of smart low cost computing devices, microphones and connectivity opportunities give the chance to create and use noise monitoring sensors, able to be employed for widespread and long-term noise assessment activities.
Compared to standard noise monitoring networks, adopting Class I sound level meters, the lower costs of the instruments are evident, even if the installation, maintenance and quality control costs are important items of the total budget, due to the long term period of measurement and, particularly, to the lack of reliability and stability of the measuring devices. The relative low cost, the possibility to build the sensors, assembling the different parts, with low manufacturing cost, the small size of the elements and the opportunity of long-term and extensive measurement employment are the main advantages of smart typologies of devices. Long-term stability, defined by difference between the measured values obtained at the beginning and at the end of a defined measurement period, mainly due to the effect of prolonged outdoor exposure, is the most disadvantage of the smart sensors. Research activity is particularly focused on MEMS (Micro-Electro-Mechanical-Systems) microphones, which become competitive compared to standard measurement equipment, and on development of techniques able to improve their quality. Many methods have been developed related to the anomaly events detection and to self-calibration techniques. Noise monitoring sensors need to be periodically recalibrated, requiring maintenance visits and, in order to avoid measurement data inaccuracy due to deviations from the calibration value, self-calibration methods have been developed. A method related to a statistical technique based on linear regression has been built up by the National Physical Laboratory (NPL), which also tests a macro sized MEMS microphone cluster prototype, able to be used for assessing autonomous calibration algorithms. This statistical method for the assessment of stability in noise monitoring networks is a variation of the Chow test. It is based on the linearity and time invariance properties that characterize any part of measurement equipment and it has been applied between monitoring sensors located in different areas, particularly it was tested using data set of SenseAble Pisa project, resulting a very useful tool. The main common characteristics arising from analyzed projects are reported in Table 1. The results show that it is possible to find a satisfactory frequency response in the range from 20 Hz to 20 kHz and floor noise value of 30-35 dB(A). The low-cost sensors show very frequently their congruence with Class II requirements, according to IEC 61672-1 standard. Smart low-cost noise monitoring systems, allowing an extensive and long-term noise monitoring, in medium sized territorial scale as urban area, seem to be able to ensure an appreciated quality output measurement data.
LIFE MONZA project foresees a noise monitoring campaign in pilot area of Libertà district, conducted using sound level meters of class I precision, and also using a smart low-cost monitoring system developed within the project (*Action B.3 Prototype of monitoring system for Noise LEZ design - data analysis techniques definition*). The main characteristics of the prototype system for smart noise monitoring activities, to be used as a continuous monitoring unit in the ex ante and ex post scenarios, have been shared with UNIFI (University of Florence), partner responsible of the development of the prototype. The main technical specifications are as following reported:

- acoustic parameters: overall A-weighted continuous equivalent sound pressure level, L_{Aeq} and continuous equivalent sound pressure level, L_{eq}, as 1/3 octave band spectrum data;
- timing for data recording: data will be registered 1 second based to permit the recognition of unusual events will be advisable in the post analysis phase;
- timing for data transmission: data will be sent every hour;
- data transmission network: will be assessed according to parameters like distance among sensors;
- power supply: solar panel (expected size 20cm x 30cm) and battery for energy storage;
- sensors location: on streetlight, height 4 m;
- ¼ or ½ - inch condenser low cost microphones;
- floor noise = 35 dB(A)
- weather protection

These requirements will be subsequently defined in detail and they could be modified, if some other better conditions will be detected.

A1.3 Operational Context: Air Quality Monitoring Systems

Conceptual Framework on LEZs

LEZs European cases of impact assessment on air quality	
London urban area. 2007-2008 (Jones at al., 2012).	In the period from the end of 2007 until 2008 it was implemented the introduction of “sulphur free” diesel fuel and the London Low Emission Zone for heavy goods vehicles in the London urban area. A great reduction in particle number concentration was occurred in London (59%) in a monitoring site used to assess the impact on air quality. This large reduction was mainly due to the “sulphur free” diesel measure and secondly correlated with the introduction of London’s LEZ.
17 German cities 2005 - 2009 (Morfeld P. et al., 2014).	The impact assessment of LEZs on nitrogen oxides air concentration was analysed The effect of LEZs on nitrogen oxides levels was estimated as a mean reduction of 2 $\mu g/m^3$ (4%).
Munich (Germany) since 2008. (Fensterer V.et al., 2014).	Munich (Germany) has been establishing a LEZ and transit bans for heavy duty vehicles since 2008. The observed concentration of PM_{10} were reduced by between 4.5% (urban background monitoring site) and 13% at traffic monitoring site
Milan (Italy) (Invernizzi G. et al., 2011).	A black carbon monitoring campaign was carried out in Milan (Italy) to estimate the potential impact of the congestion traffic charge zone (in the Ecopass zone, all vehicles prior Euro 4 standards have to buy a ticket) and the new pedestrian zone on air quality (Invernizzi G. et al., 2011). Black carbon and PM mass concentrations was analysed in three different days and in three different site. The first site was located outer the Ecopass zone, the second one within Ecopass zone and the last one in the pedestrian area. A reduction by 47% (Ecopass zone) to 62% (pedestrian zone) was found in the ratio of Black Carbon to PM_{10}.

Description

Low emission zones (LEZs) have been established to reduce air pollutant emissions and to improve urban air quality in European countries. LEZs usually regulate the access to a zone depending on the vehicle emission standards or the vehicle type (heavy-duty vehicles, light-duty vehicles, moped etc.). LEZs may cover a variable area that can include few roads or a large part of an urban area. Those zones aims mainly at reducing exhaust emissions of traffic related pollutant, particularly PM and nitrogen oxides NO_X. Policy measures (as LEZs) to reduce traffic by banning the most polluting vehicles are generally able to reduce circulating vehicles but they gave conflicting results on air pollution level. Evaluate the effect of a LEZ on pollution level (PM_{10}, $PM_{2.5}$, NO_X) is not an easy task because of several confounding factors: meteorological conditions, regional background levels of pollutants, other concomitant air quality policy measures (Holman C. et al., 2015). To assess the impact of the LEZs, taking into account the confounding factors, it needs to remove the influence of non local traffic pollution sources. Advanced statistical techniques are necessary to achieve this aim.

Meteorology has a great impact on yearly and daily variation of PM concentration and therefore it is necessary make adjustment over long periods to remove seasonal biases. Such circumstance makes even more difficult assessing the environmental impact of LEZs in terms of PM level reduction with regard to the short term air quality standards.

When the contribution of exhaust emissions from local traffic to PM concentration levels is very small compared to the contribution of other emission sources and to secondary PM (regional background), the reduction achievable with the LEZ implementation has, very often, a negligible impact on PM mass concentration levels. Such situation is typical in the region of our study (Po valley region). Focusing on specific components of PM, like black carbon, or parameter (e.g. particle number concentration) more related with exhaust vehicles emission seems to be more suitable for assessing the impact of LEZs on local scale air quality (C. Holman et al., 2015), particularly when the LEZs involve traffic restriction for heavy duty diesel vehicles (Jones at al., 2012).

The other concomitant air quality/transport/energy policy measures (e.g. implementation of Euro standards, vehicle fleet composition change, etc.) represent relevant confounding factors, and affect the evaluation process making hard to isolate the impact of LEZs on air quality.

Air quality assessment strategy

Macrositing and micrositing criteria concerning fixed and passive sampling	
European Directive 2008/50/EC	Macroscale siting criteria Microscale siting criteria
Brunekreef, 2008; Cyrys et al., 2012	Other criteria for siting passive samplers, to assess ambient air quality by indicative measurement, are suggested in the ESCAPE Study manual and related scientific literature Guidelines for the selection of sites Microenvironmental criteria for site selection Other practical criteria
Guide Demonstration of Equivalence of Ambient Air Monitoring Methods (EC-JRC, 2008)	The procedure of demonstration of equivalence for diffusive samplers
European Standard (EN 16339-2013)	Specifies a method for the sampling and analysis of NO_2 in ambient air using diffusive sampling. The collected NO_2 is extracted as nitrite using water. The resulting extract may be analyzed by: — Colorimetry after derivatization of the nitrite, using the Griess-Saltzman method (Atkins et al., 1986); — Ion chromatography with conductivity detection (Miller et al., 1984). It can be used for the NO_2 measurement in a concentration range of approximately 3 µg/m³ to 130 $\mu g/m^3$.
European Standard UNI EN 14662-5	Gives general guidance for the sampling and analysis of benzene in air, by diffusive sampling.
EN 13528-2, 2003.	Ambient air quality - diffusive samplers for the determination of concentrations of gases and vapours - Requirements and test methods. Part 2: Specific requirements and test methods.
EN 13528-3, 2004.	Ambient air quality - diffusive samplers for the determination of concentrations of gases and vapours - Requirements and test methods. Part 3: Guide to selection, use and maintenance.
EN 14662-5:2005	Ambient air quality - Standard method for measurement of benzene concentrations - Part 5: Diffusive sampling followed by solvent desorption and gas chromatography
EC,DG ENV, May 2010	Guidance on air quality assessment under the Air Quality Directive 2008/50/EC
EC, JRC - Institute for Environment and Sustainability. 2009	Hafkenscheid T., et al. Review of the application of diffusive samplers in the European Union for the monitoring of nitrogen dioxide in ambient air.

Description

To assess the exposure gradients within a city as well as to assess the effectiveness of measures addressed to reduce the air pollution, reliable estimate of both temporal and spatial variability in the study domain are needed. Two general approach can be identified as for assess small scale spatial variability: deterministic modelling (i.e. dispersion model) and empirical modelling (e.g. land use regression). Whatever the modelling approach, fixed point measurement are used to develop and or to validate the models. Thus, ad hoc monitoring are needed, since routine networks in most urban areas are not dense enough. In fact, existing monitoring networks have insufficient density to capture small-scale spatial variation of air pollution. Moreover several areas, particularly small-medium cities in Italy, have only 1-2 fixed sites belonging to the regional air pollution monitoring network, if any. Furthermore, purpose-designed monitoring allows the investigators the control over the type of sites (e.g. traffic, background) they wish to include in model development.

Disadvantages of purpose-designed monitoring include the additional cost and the limited temporal coverage of the measurements. To date, most purpose-designed monitoring campaigns consisted of between one and four 7–14 days sampling campaigns, spread over a full year, in order to catch the seasonal variability, whereas routine monitoring is typically continuous, especially for the gaseous components.

A correct location of monitoring equipments is a crucial aspect in air quality assessment.

An adequate choose of macro and micrositing criteria to be adopted can be based on European AQ directives and scientific literature references and research experience. Other criteria for siting passive samplers, to assess ambient air quality by indicative measurement, are suggested in the ESCAPE Study manual and related scientific literature (Brunekreef, 2008; Cyrys et al., 2012). Sampling sites will be selected to represent the spatial variation of air pollution in the study domain. Monitoring sites will be selected with help according to Regional Environmental Agencies know-how together with available maps and satellite data. Sampling sites should be classified in regional, suburban and urban background and street traffic oriented and industrial sites.

Diffusive sampling technique are of particular interest, because of their relatively low cost, no need of any pump or electrical power and simple operation, allowing for deploying a large number of samplers over the study area.

A diffusive sampler is a device which is capable of taking samples of gases or vapours from the atmosphere at a rate controlled by a physical process such as gaseous diffusion through a static air layer or a porous material and/or permeation through a membrane, but which does not involve the active movement of pumped air through the device.

The diffusive samplers are suitable for long-term monitoring of several gases in ambient air (e.g. nitrogen oxides, ozone, several volatile organic compounds).

Assessment of spatial variability

LUR model's development – ESCAPE approach	
Significant predictors	- traffic-related variables (distance to the nearest road, road length, traffic density), - population density in the census area, - land use information offered by Corine Land Cover (e.g. high and low density residential area, urban green) - physical geography (latitude and longitude), - meteorological parameters (temperature, wind velocity, pressure, precipitation, mixing height) - emission data - enhanced variables can be offered to account for the effects of building volume, road and width length (street canyon)
LUR model development standardized approach European Study of Cohorts for Air Pollution Effects (ESCAPE) (Eeftens et al, 2012).	- stepwise forward regression method should be applied to develop the model from a large set of predictor variables that maximizes the percentage of explained variability (R^2, R^2 adjusted) and minimizes the Root Mean Square Error (RMSE). - Step 1: model starts with the variable that maximizes the adjusted R^2; in every iteration, all the potential predictor variables were entered independently. - The predictor variable, producing an increase in the adjusted R^2 higher than 1%, was added to the model if the direction of the association with pollutant was as expected. - The predictor variable, producing an increase in the adjusted R^2 higher than 1%, was added to the model if the direction of the association with pollutant was as expected. - Iteration until no additional variables could increase the adjusted R^2. - Covariates with p-value higher than 0.1 were sequentially removed from the model. - Standard diagnostic tests for ordinary least regression (t-test, influential observation by Cook's Distance, homoschedasticity, normality of the residuals and spatial autocorrelation) should be applied to the final model to assess the linearity and independence of errors assumptions. - model validation through Leave-One-Out Cross Validation (LOOCV)

Description

Current methods for assessing intra-urban air pollution spatial variability have recently been reviewed (Jerrett et al., 2005). Conventional dispersion models and empirical techniques, in particular geo-statistical interpolation methods and Land Use Regression models (LURs), were the most common approaches described in most of the studies. Application of LUR model was introduced for the first time in the SAVIAH (Small Area Variations in Air quality and Health) study (Briggs et al., 1997). After the successful pioneering work in SAVIAH, LURs have been getting increasingly: further developments have been focalized on additional variables (Rosenlund et al., 2008, Arain et al., 2007,), transferability to other locations, combination with dispersion model outputs (Zwack et al., 2011) and, more recently, on spatio-temporal aspects (Patton et al, 2014).

To evaluate the efficacy of Low Emission Zones (LEZ) in urban areas, the models that were commonly used to give a reliable estimations of air pollution, were dispersion models (photochemical or lagrangian model in according to the scale of impact and the complexity of scenario's simulation). However, in recent years, LURs have been achieved best performances and results in order to capture small scale variations in air pollution concentrations, particularly from traffic sources, with sensible low costs. In fact, higher spatial resolution of pollutant concentration estimation with a cost-effective approach was the main improvement of LURs in comparison to other techniques.

LURs have been performed particularly in North America and Europe within a number of studies in the last two decades (Hoek et al., 2008).

LURs combine experimental measures of air pollutants at various locations representative of the study area, and the development of a regression model using predictor variables, obtained through geographic information system (GIS). Development in GIS have contributed to the popularity of LUR methods.

Pollutant measurements were the dependent variable. A spatially network of pollutant monitoring sites (20 – 80 depending on the pollutants and the size of area under investigation) must be planned: the performance of the model depends on the number and distribution of the samplers.

A1.4 Operational Context: Health Indicators

Health Indicators	
Quality of life	
Subjective rating of life quality	
Subjective ability to concentrate	
Perceived healthiness of the physical environment	
Sleep satisfaction	
Satisfaction about mode of transportation	


WHOQOL-BREF

June 1997

U.S. Version

University of Washington
Seattle, Washington
United States of America

Figure A1.4.1. The WHOQOL-BREF questionnaire. Source: University of Washington, Seattle, Washington, U.S.

Description

The assessment of *quality of life* (QOL) in social and health sciences has assumed increasing importance, as testified by the many studies published on the development and validation of accurate and reproducible methods for the overall assessment of health status to be used in association or instead of classic indicators, such as mortality or morbidity. QOL, measured by validated instruments, has become an area of investigation in some ways of even more impact respect of "hard" indicators of health, since it involves the direct participation/perception of each person both on his/her own current health status and on the kind of interventions that are or are not perceived as useful to the improvement of their living conditions. Therefore, since the second half of the 80s, many tools have been created that, with different purposes and research areas, have tried to measure the QOL in different conditions. Based on the analysis of the studies identified in the literature, therefore, we propose the use of the WHOQOL-Bref questionnaire that, although less used than the SF36 questionnaire, is the only tool that has a specific environmental domain. administration pre-post of WHOQOL-Bref would provide a comparable objective score of the residents' QOL and an estimate of the potential role of the structural changes on it. The 26-item tool requires a compilation time - min 5, max 10 mins – that we submit to the evaluation of the steering committee: if on the one hand the complete administration of all the items enables comparisons with similar scientific studies, the limit of the physical space available in the general LIFE questionnaire, as well as a possible negative effect on the participants due to the excessive length of the compilation, has led us to select a minimum of five main questions to be administered, that we propose as an enlarged general assessment, bearing in mind that the results obtained would have only an internal validity and representativeness. That is, in case the steering committee will decide to adopt the "minimum" approach, the results will be valid only for the sample of the study, but not generalizable nor comparable to other similar researches. Alternatively, we proposed the full administration of the WHOQOL - Bref questionnaire in two possible differente ways:

1. administration of the complete WHOQOL-Bref questionnaire to the entire sample of Monza citizens, attaching it in the overall questionnaire;
2. administration of the 5 selected questions in the overall questionnaire and enclose the entire WHOQOL-Bref as a separate module, letting the participants the willingness/ability to respond to it.

The choice of one of these last two modalities could warrant a greater representativeness but it needs a greater commitment of those citizens who will join the research.

Health Indicators	
Annoyance	
Subjective rating of perception of annoyance due to noise pollution	
Perceived main sources of noise pollution	
Perception of nuisance due to noise pollution by time slots	
Experienced clinical phenomena due to noise pollution	

Variables	Leisure (%)	Work (%)	Home (%)	Total population (%)
Annoyance				
None	80.0	51.6	43.3	58.3
Little	20.0	26.7	8.4	18.3
Moderate	—	10.0	10.0	6.7
Highly	—	11.7	38.3	16.7

Table A1.4.1. Perception of annoyance caused by exposure to noise according to the interviewees in each urban soundscape (leisure, work and home) in Porto, Portugal, 2012. Source: de Paiva Vianna KM, Alves Cardoso MR, Rodrigues RM. Noise pollution and annoyance: an urban soundscapes study.
Noise Health 2015; 17(76): 125-33. doi: 10.4103/1463-1741.155833.

Description

Noisy environments may produce in exposed people several behavioral and social effects. The effects of urban noise are often complex and indirect; many of these effects must also be considered as the result of the interaction with a number of non-acoustic variables.

Socio-acoustic studies indicate that behavioral effects may be considered as a consequence of exposure to noise. Therefore, an acoustically unfavorable environment constitutes a bias factor for a good quality of life. This is a condition that can manifest itself through a series of extra-auditory effects, including sleep disturbance, interference with speech communication, psychophysiological effects, disturbances of performance and learning, and annoyance.

Annoyance may be defined as a feeling of displeasure related to the noise (as well as to any agent or condition) that the individual knows or suspects, and that affects him/her in a negative way . It is not just a result of a non-optimal sleep or an interference with communication, but it also depends on less well defined feelings as the perception of being disturbed and affected during all the activities and the rest. In other words, annoyance, for years considered as the most obvious and immediate effect of exposure to noise, is a general term used to summarize all the negative feelings as disturbance, dissatisfaction, displeasure, and irritation tried by the person exposed.

Annoyance, intended as a parameter for the noise disturbance quantification, can become an excellent indicator in order to study and improve, from an acoustic point of view, the quality of life. The study of this phenomenon in urban areas has developed over the last 30-40 years and, consequently, the knowledge on this subject is, to a large extent, recent. Since this is a set of subjective feelings, the detection of annoyance is normally carried out through questionnaires administered to large groups of people. However, to date, in the literature, we did not find the existence of an authoritative and validated questionnaire for the detection of this disturbance. Consequently, we have developed a brief survey instrument, made up of 4 questions, to complement the minimum dataset of 5 selected questions by the WHOQOL-Bref.

A1.5 Operational Context: Interventions and expected effects on air quality, noise and health

TABLE OF CONTENTS			
List of key-words and abbreviations: LEZ area, interventions, effects, air quality, noise, health.			
Number of typology of intervention	Typology of intervention	Number of the schedule on the specific intervention	Specific intervention
1	Low Noise Pavings	1.1	Use-surface “open graded”
		1.2	Use-surface “gap graded”
		1.3	Use-surface “dense graded”
		1.4	Use-surface “microtappeto”
		1.5	Use-surface “dense graded with expanded clay”
		1.6	Use-surface “gap graded with the addiction of polymers SBR/NR”
2	Interventions on traffic regulation	2.1	Chicane/road narrowings
		2.2	Roundabouts
		2.3	Speed bumps
		2.4	Safety islands
		2.5	Electronic devices for speed control
3	Strategic Actions	3.1	Urban Traffic Plan
		3.2	Public electric vehicles
		3.3	30 km/h zones
4	Noise barriers	4.1	Traditional noise barriers
		4.2	Low barriers

INTRODUCTION

Action A1 consists in a state-of-the art review about the legislative and technical requirements on noise LEZ as well as the most up-to-date noise and air quality monitoring systems.
The necessity is to update the current state of knowledge about the improvements concerning the technological and normative framework of the above-mentioned items of the Project, including a scientific review on the suitable health indicators of the effects due to noise and air pollution.
The action is divided in 5 sub-actions, each one coordinated by one associated beneficiary:
A1.1 Legal and Environmental framework for Noise LEZ introduction - MONZA
A1.2 Operational context: Noise Monitoring Systems - ISPRA
A1.3 Operational context: Air Quality Monitoring Systems - ISPRA
A1.4 Operational context: Health indicators - UNIFI
A1.5 Operational context: interventions and expected effects on air quality, noise and health – VIENROSE
In sub-action A1.5 the analysis of the state of the art about possible interventions into LEZ areas and their effects on air quality, noise and health have been performed. The most recent available design solutions for noise abatement, air quality improvement and positive effects on health in urban areas have been collected.
In particular, a field survey among all literature, specialized magazine, technical papers, results coming from EU-founded projects has been carried out.
The survey has been mainly focused on the effects of: low noise paving, interventions on traffic regulation, strategic actions and noise barriers.
Referring to the choice of the typology of low noise paving, special attention has been reserved to results of “Leopoldo Project” (a project at regional level, coordinated by Tuscany Region) that gives guidelines for planning, construction, control and maintenance of the paving of the ordinary roads. At this time, the results of Leopoldo phase 1 (related to the implementation of low noise paving in extra-urban contexts) are available and consequently reported in the abacus. In the next future, results from the on-going Leopoldo phase 2 (related to the implementation of low noise paving in urban contexts) are expected to be collected (on the base of networking activities established with the Leopoldo project partners) and upgraded in the abacus.
Referring to other design solutions (Intervention on traffic regulation, strategic actions and noise barriers) special attention has been reserved to results of “Hush Project” (www.hush-project.eu) and “SONORUS Project” (www.fp7sonorus.eu).
Referring to noise barriers in urban contexts some interesting solutions have been found in the experiences and results of “QUADMAP Project” (www.quadmap.eu) and “SONORUS Project”.
Referring to the effects on health and safety special attention was paid on the report “Urban traffic calming and health”(November 2011) by National Collaborating Centre for Healthy Public Policy (Quebec).

Low noise paving	Interventions on traffic regulation	Strategic Action: 30 km/h zone	Noise barrier
			
Figure: example	Figure: example	Figure: Area Brozzi- Quaracchi, Firenze - Italy Source: Hush Project Link: www.hush-project.eu	Figure: “Dionisi” School, Firenze - Italy Source: Quadmap Project Link: www.quadmap.eu

1. TIPOLOGY OF INTERVENTION				
Field of application: urban/extra-urban, ecc..				
1.0 SPECIFIC INTEVENTION (FOR EVERY TIPOLOGY CONSIDERED)	**Location:** ________	**Name of the tested street:** ______ **Mileage:** ______	**Typology of location:** ______ **Altimetry** ______	
Layers of the paving				
Traffic Data	**Hourly flow**	**Light vehicles**	**% Heavy vehicles**	
Average of Traffic in a day (24 h)	Number of vehicles passed during one hour	Number of light vehicles	Percentage of heavy vehicles	
Rolling noise - CPX at 50 km/h				
Date	Period between paving and testing [months]	Reference scenario (Srif) [dB(A)]	Experimental scenario (Ssp) [dB(A)]	Difference Srif-Ssp [dB(A)]
month- year	number of months	scenario without low noise paving	scenario with low noise paving	Difference between scenario without low noise paving and scenario with low noise paving
Level of roadside noise – SPB a 50 km/h				

General description of the intervention

____

Image	Particle size curve – use-surface Chart	Rolling noise – CPX Chart	Level of roadside noise – SPB Chart
Source: Link:			

1. LOW NOISE PAVINGS

Field of application: extra-urban

1.1 USE-SURFACE "OPEN GRADED"	**Location:** Arezzo Marcena	**Name of the tested street** SRT 71 *Umbro Casentinese* **Mileage:** km 156+866/157+0.44	**Typology of location:** hill **Altimetry:** 260m s.l.m.

Layers of the paving

LAYER	THICKNESS	MATERIAL
USE-SURFACE	5 cm	Use surface with bituminous mixture "open graded" + SAMI (Stress absorbing Membrane Interlayer)
BINDER	6 cm	Binder layer with traditional bituminous mixture
BASE	12 cm	Base layer with traditional bituminous mixture

Traffic Data	Hourly flow	Light vehicles	% Heavy vehicles
TGM	8916	7286	18.3

Rolling noise - CPX at 50 km/h

Date	Period between paving and testing [months]	Reference scenario (Srif) [dB(A)]	Experimental scenario (Ssp) [dB(A)]	Difference Srif-Ssp [dB(A)]
June 2008	1	93.3	89.6	3.7
July 2012	51	94.2	90.5	3.7

Level of roadside noise – SPB a 50 km/h

Date	Period between paving and testing [months]	Noise levels L1 at 50 km/h [dB(A)]			
		L1 a h=1.2 m	ΔL1 a h=1.2 m	L1 a h=3.0 m	ΔL1 a h=3.0 m
march-06	Ante-operam	72.4		74.6	
july-08	2	66.7	-5.7	66.4	-8.2
july-09	14	65.4	-7.0	66.1	-8.5
november-09	18	73.4	1.0	73.7	-0.9
april-11	35	71.0	-1.4	71.5	-3.1
september-11	40	70.8	-1.6	72.3	-2.3

Low noise pavings

Use-surface "open graded"

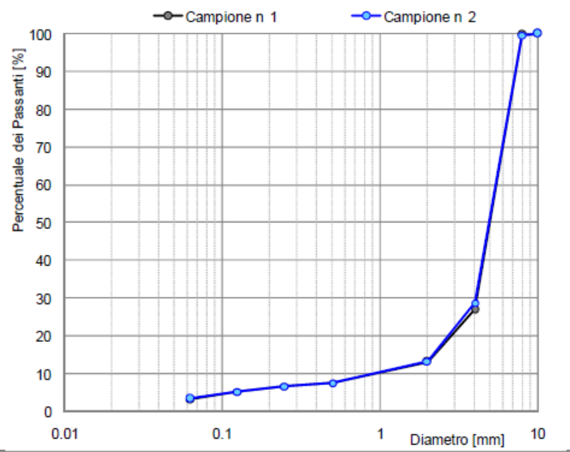
Use-surface open graded are mixtures that, thanks to the particular particle size characteristics and to the high quality of the materials, allow to optimize the acoustic performance without compromising the durability, stability and safety. The contribution to road safety of these use-surface is high, suggesting their increased application in both the construction of new pavings, both in renovation of the existing paving.

They are draining and sound-absorbing mixtures (CDF) with a work thickness of at least 40 mm. The mixtures for use-surface open graded are constituted by crushed stones, little sand and filler, hot kneaded with modified bitumen that, after compacting, have an intercommunicating porosity 4 or 5 times higher than that of a traditional conglomerate for use-surface. This conglomerate, high-tech, so has high surface roughness: has draining and sound-absorbing function, providing a good grip even in wet weather.

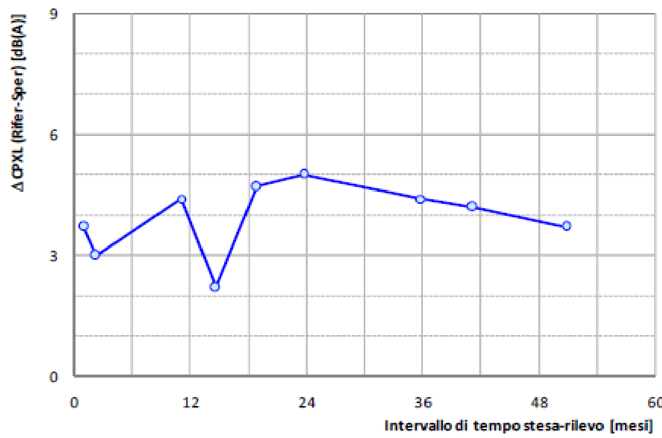
From the point of view of sound, it has a maximum absorption in the frequency range 800-1000Hz. This characteristic is maintained over time even if there is an absorption attenuation, due to the gradual filling of the voids, caused by the action of dirt over the years. Regarding the emission due to contact between tire and paving, after four years we can appreciate a reduction in noise levels compared to the reference paving of about 3.7 dB (A). Concerning noise level at the roadside, measures unfortunately have been suffering from a number of problems both meteoclimatic both technical, however it was observed a progressive reduction of the ante-post difference from an initial value of ca. 7 dB (A) up to the value of 1.6 dB (A) obtained in the September 2011 session. Regarding the emission spectra, results followed those already expected with sound absorption, therefore a lowering of levels for frequencies exceeding 800 Hz, although this trend is much less evident in the spectra obtained at roadside, characterized by a strong variability in time.

Image

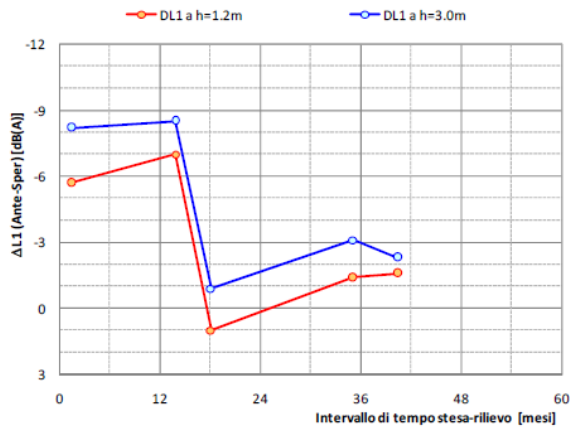
Particle size curve – use-surface



Rolling noise – CPX



Level of roadside noise – SPB



Source: Leopoldo1 Project Link: www.arpat.toscana.it/documentazione/report/progetto-leopoldo201d-relazione-finale-fase-ii-2012

1. LOW NOISE PAVINGS

Field of application: extra-urban

1.2 USE-SURFACE "GAP GRADED"	**Location:** Firenze Lutiano Vecchio	**Name of the tested street** SRT 302 *Faentina* **Mileage:** km 27+304/27+548	**Typology of location:** hill **Altimetry:** 244 m s.l.m.

Layers of the paving

LAYER	THICKNESS	MATERIAL
USE-SURFACE	3 cm	Use surface with bituminous mixture "gap graded"
BINDER	6 cm	Binder layer with traditional bituminous mixture
BASE	12 cm	Base layer with traditional bituminous mixture

Traffic Data	Hourly flow	Light vehicles	% Heavy vehicles
TGM	3203	2828	11.7

Rolling noise - CPX at 50 km/h

Date	Period between paving and testing [months]	Reference scenario (Srif) [dB(A)]	Experimental scenario (Ssp) [dB(A)]	Difference Srif-Ssp [dB(A)]
July 2008	1	93.7	87.4	6.3
July 2015	50	91.7	90.4	4.4

Level of roadside noise – SPB a 50 km/h

Date	Period between paving and testing [months]	Noise levels L1 at 50 km/h [dB(A)]			
		L1 a h=1.2 m	ΔL1 a h=1.2 m	L1 a h=3.0 m	ΔL1 a h=3.0 m
February-06	Ante-operam	72.0		72.7	
march-09	9	65.4	-6.6	66.1	-6.6
july-09	14	65.3	-6.7	67.3	-5.4
november-09	18	68.4	-3.6	69.9	-2.8
july-10	26	68.3	-3.7	68.3	-4.4
october-10	29	69.9	-2.1	69.6	-3.1
may-11	36	70.9	-1.1	70.5	-2.2
september-11	40	70.2	-1.8	69.9	-2.8

Low noise pavings

Use –surface "gap graded"

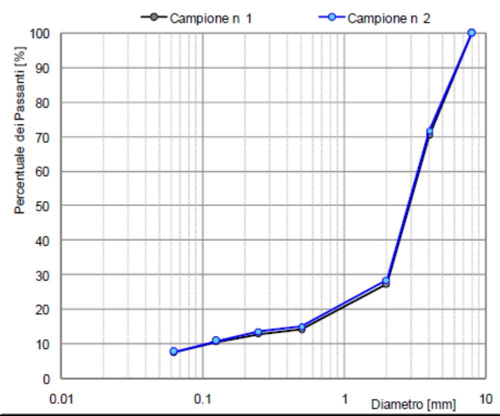
Use-surface gap graded are mixtures that, thanks to their particular particle size characteristics and high quality of materials, allow to optimize the acoustic performance without compromising durability, stability and safety of circulation. Contribution to road safety of these use-surfaces is high, suggesting an increasing application both in construction of new paving, both in renovation of the existing paving.

Gap graded conglomerates are non-slip wear carpets, having thicknesses in work of at least 30mm, consisting of a mixture of crushed stones, sands obtained only from crushing and additive (filler), hot kneaded in special plants with modified bitumen, and sometimes with the addition of organic or mineral fibers. This conglomerate, closed and totally impervious to the underlying layers, is proposed as an alternative to draining sound-absorbent for enhanced possibilities of application and for easier maintenance. It is designed to: improve adherence, waterproofing the underlying structure and reduce the tire rolling noise.

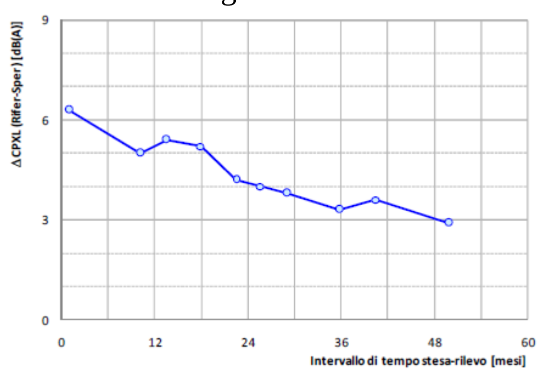
From an acoustic point of view, paving, being of closed type, shows no particular absorbent characteristics, showing low absorption at frequencies above 3000 Hz. This feature has changed over time since absorption is globally decreased over the years, due to the settling of paving. Regarding the emission due to contact between tire and paving, is observed in time a progressive increase in noise level and after four years, reduction has stabilized on about 3 dB (A). Concerning noise level at the roadside, results fully confirm what was seen with CPX measures, that is, a progressive worsening of noise of paving. It is observed, both for the emission due to contact between tire and paving both for those at roadside, a slight shift of emission spectrum toward low frequencies.

Image

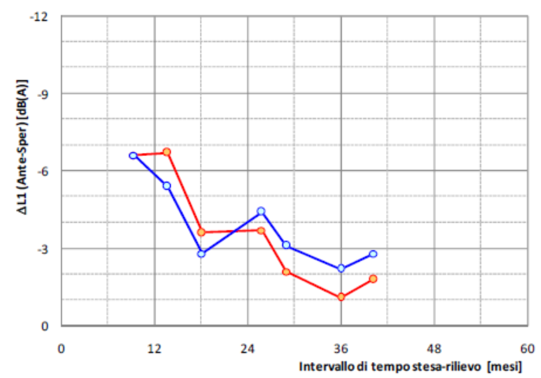
Particle size curve – use-surface



Rolling noise – CPX



Level of roadside noise – SPB



Source: Leopoldo1 Project Link: www.arpat.toscana.it/documentazione/report/progetto-leopoldo201d-relazione-finale-fase-ii-2012

1. LOW NOISE PAVINGS

Field of application: extra-urban

1.3 USE-SURFACE "DENSE GRADED"	**Location:** Lucca Maggiano	**Name of the tested street** SRT 439 *Sarzanese Valdera* **Mileage:** km 21+786/21+986	**Typology of location:** hill **Altimetry:** 50 m s.l.m. Campo di applicazione:

Layers of the paving

LAYER	THICKNESS	MATERIAL
USE-SURFACE	3 cm	Use surface with bituminous mixture "dense graded"
BINDER	5 cm	Binder layer with traditional bituminous mixture
BASE	10 cm	Base layer with traditional bituminous mixture

Traffic Data	Hourly flow	Light vehicles	% Heavy vehicles
TGM	2374	2223	6.4

Rolling noise - CPX at 50 km/h

Date	Period between paving and testing [months]	Reference scenario (Srif) [dB(A)]	Experimental scenario (Ssp) [dB(A)]	Difference Srif-Ssp [dB(A)]
July 2008	1	91.6	87.1	4.5
July 2012	50	93.7	88.8	4.9

Level of roadside noise – SPB a 50 km/h

Date	Period between paving and testing [months]	Noise levels L1 at 50 km/h [dB(A)]			
		L1 a h=1.2 m	ΔL1 a h=1.2 m	L1 a h=3.0 m	ΔL1 a h=3.0 m
february-06	Ante-operam	68.3		71.4	
february-09	9	64.6	-3.7	66.5	-4.9
july-09	14	63.6	-4.7	65.2	-6.2
october-09	17	65.8	-2.5	68.3	-3.1
april-10	23	63.8	-4.5	66.1	-5.3
may-11	36	64.2	-4.1	67.0	-4.4
september-11	40	64.5	-3.8	67.1	-4.3
august-12	51	64.8	-3.5	67.5	-3.9

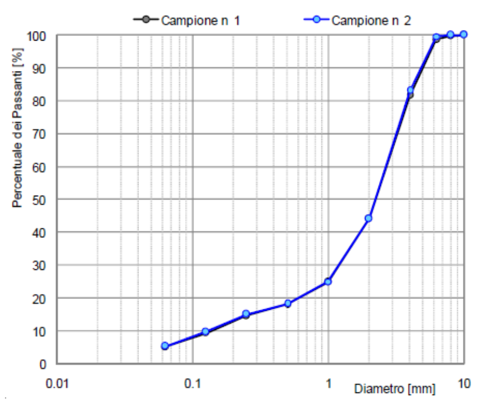
Low noise pavings

Use-surface "dense graded"

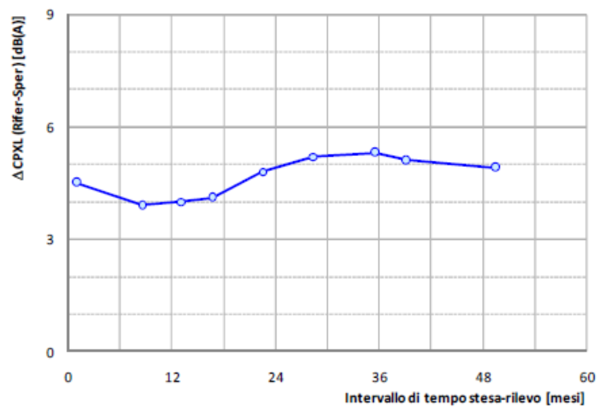
Use-surface dense graded are mixtures of bituminous conglomerate of the closed type having granulometric characteristics such as to reduce, compared to traditional use-surfaces, sound emissions generated by wheel/paving contact . The decrease in rolling noise is solely due to the particular particle size range, which allows to obtain use-surface with texture characteristics such as to reduce noise produced by resonance phenomena which are generated during wheel/paving contact. For this reason we speak of use-surface with optimized texture dense graded.From the acoustic point of view, the paving, being closed, shows over time no worthy relief absorption, with a modest initial uptake to 500 Hz immediately disappeared. As it regards the tire/paving contact emission is observed over time a trend not perfectly constant in time, however with differences with respect to the reference between 4 and 5 dB (A), and this reduction, after four years, has attested of about 5 dB (A). Regarding noise level at roadside, the results fully confirm what was seen with the CPX measures, that is a substantial constancy of differences ante-post, greater than 4 dB (A) after four years, even if the measure is characterized by a large statistical fluctuation. Regarding noise frequency spectrum generated from paving in case of CPX measurements is observed the substantial equality between ante and post-operam spectrum, with a slight predominance of low frequencies, while for measures at roadside we can notice a marked predominance of low frequencies in low-noise paving.

Image

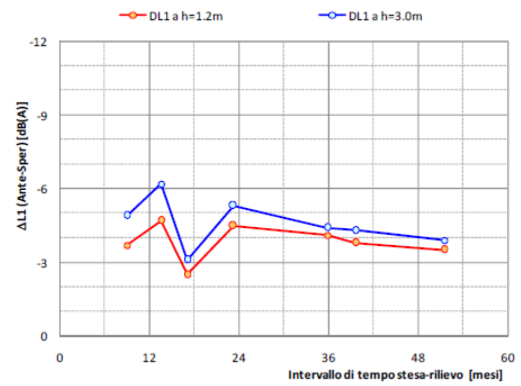
Particle size curve – use-surface



Rolling noise – CPX



Level of roadside noise – SPB



Source: Leopoldo1 Project Link: www.arpat.toscana.it/documentazione/report/progetto-leopoldo201d-relazione-finale-fase-ii-2012

1. LOW NOISE PAVINGS

Field of application: extra-urban

1.4 USE-SURFACE "MICROTAPPETO"	**Location:** Massa Carrara Codiponte	**Name of the tested street** SRT 445 *della Garfagnana* **Mileage:** km 63+345/63+545	**Typology of location:** mountain **Altimetry:** 280 m s.l.m.

Layers of the paving

LAYER	THICKNESS	MATERIAL
USE-SURFACE	2 cm	Use surface "microtappeto"
BINDER	6 cm	Binder layer with traditional bituminous mixture
BASE	10 cm	Base layer with traditional bituminous mixture

Traffic Data	Hourly flow	Light vehicles	% Heavy vehicles
TGM	781	657	15.9

Rolling noise - CPX at 50 km/h

Date	Period between paving and testing [months]	Reference scenario (Srif) [dB(A)]	Experimental scenario (Ssp) [dB(A)]	Difference Srif-Ssp [dB(A)]
November 2010	1	96.4	89.3	7.1
July 2012	21	94.3	88.6	5.7

Level of roadside noise – SPB a 50 km/h

Date	Period between paving and testing [months]	Noise levels L1 at 50 km/h [dB(A)]			
		L1 a h=1.2 m	ΔL1 a h=1.2 m	L1 a h=3.0 m	ΔL1 a h=3.0 m
october-06	Ante-operam	68.2		68.1	
may-11	7	65.0	-3.2	65.7	-2.4
september-11	12	63.1	-5.1	63.8	-4.3
july-12	22	62.8	-5.4	63.7	-4.4

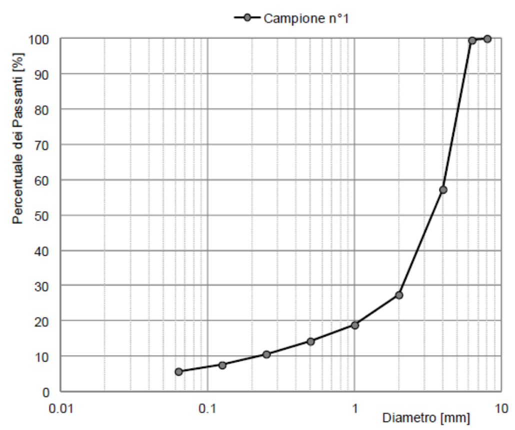
Low noise pavings

Use-surface "microtappeto"

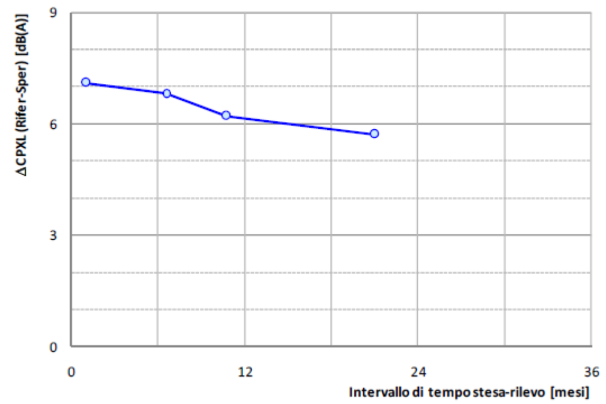
The use-surfaces "microtappeto" are used for the realization of special low noise emission use-surface. Thanks to the particle-size features and the high quality of materials, these open graded mixtures permit to optimize the acoustic performance without compromising the durability, stability and safety. These membranes bring a high contribution to road safety, suggesting their increased application both in construction of new paving and in use-surface makeover of existing paving.The draining asphalt is used to make the particle-surface thickness between 20-25 mm, characterized by a high surface roughness, partially draining and sound-absorbing. From the acoustic point of view, the paving, being open-ended, initially shows a good absorption, which slowly has decreased over time because of the gradual filling of voids. The initial maximum absorption was 0.63 that became 0.19, measured in the July session 2012. Initially the spectrum has a first absorption peak at 800 Hz and a second peak at 1600 Hz, a little more stable over time. Concerning the tyre/paving contact emission, we can notice a slow decrease of the difference compared to the reference, but still greater than 5.8 dB (A), measured difference during the July 2012 session. Concerning noise roadside, the results fully confirm what was seen with the CPX measurements, that is a progressive attenuation of the ante/post difference, however, two years after the asphalting, is about 5.4 dB (A). Even if the measurements is characterized by a large statistical fluctuation due to low volumes of traffic and strong variability in the manner of driving of the measured vehicles.Concerning the noise frequency spectrum generated from the paving, in the CPX measurements it is observed the substantial prevalence of low frequencies, with the characteristic emission peak between 630 and 800 Hz.

Image

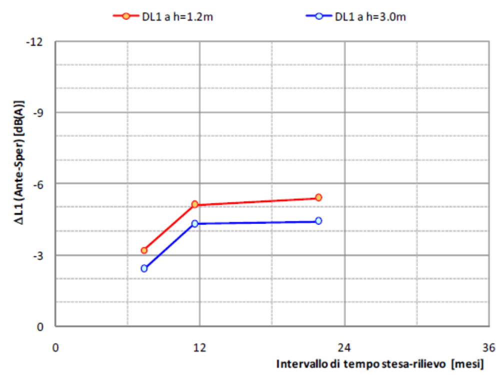
Particle size curve – use-surface



Rolling noise – CPX



Level of roadside noise – SPB



Source: Leopoldo1 Project Link: www.arpat.toscana.it/documentazione/report/progetto-leopoldo201d-relazione-finale-fase-ii-2012

1. LOW NOISE PAVINGS

Field of application: extra-urban

1.5 USE-SURFACE "DENSE GRADED WITH EXPANDED CLAY"	**Location:** Pisa La Sterza	**Name of the tested street** SRT 439 *Sarzanese Valdera* **Mileage:** km 79+208/79+408	**Typology of location:** level ground **Altimetry:** 60 m s.l.m.

Layers of the paving

LAYER	THICKNESS	MATERIAL
USE-SURFACE	4 cm	Use surface with bituminous mixture "dense graded with expanded clay"
BINDER	5 cm	Binder layer with traditional bituminous mixture
BASE	15 cm	Base layer by stabilization of foamed bitumen and concrete of materials from existent paving

Traffic Data	Hourly flow	Light vehicles	% Heavy vehicles
TGM	2616	2171	17

Rolling noise - CPX at 50 km/h

Date	Period between paving and testing [months]	Reference scenario (Srif) [dB(A)]	Experimental scenario (Ssp) [dB(A)]	Difference Srif-Ssp [dB(A)]
July 2010	1	97.6	91.2	6.4
July 2012	25	95.9	92.3	3.6

Level of roadside noise – SPB a 50 km/h

Date	**Period between paving and testing [months]**	**Noise levels L1 at 50 km/h [dB(A)]**			
		L1 a h=1.2 m	**ΔL1 a h=1.2 m**	**L1 a h=3.0 m**	**ΔL1 a h=3.0 m**
march-06	Ante-operam	71.4		74.2	
august-10	3	61.7	-9.7	62.7	-11.5
november-10	5	64.8	-6.6	64.8	-9.4
may-11	12	70.8	-0.6	69.6	-4.6
august-11	15	70.9	-0.5	70.7	-3.5
august-12	27	72.2	0.8	72.3	-1.9

Low noise pavings

Use-surface "dense graded with expanded clay"

The Use-surface, dense graded type with expanded clay are the traditional asphalt concrete mixtures in which part of aggregate consists of expanded clay.

The use of this material in the production of the surface layer of the superstructure permits to obtain closed-type use-surfaces, with granulometric characteristics that enable to reduce the noise generated by the tyre/paving contact, compared to traditional use-surface types. We can also notice the improvement of the adhesion properties and the reduction of rolling noise emissions, compared to conventional closed use-surfaces built with only natural aggregates.

In terms of adherence, such an improvement is due to the high surface microroughness having particles of expanded clay, while the reduction of noise emissions is solely due to the spherical shape of the expanded clay particles, which allow to obtain use-surfaces with specific texture characteristics to reduce the noise produced by contact between tyre and paving.

The granular composition of the mixture should be studied by volume and not by masse. This is important in design phase in order to consider correctly the different volumetric mass of lytic component and expanded clay.

From an acoustic point of view, the paving, being of closed type, does not show any significant absorption over time.

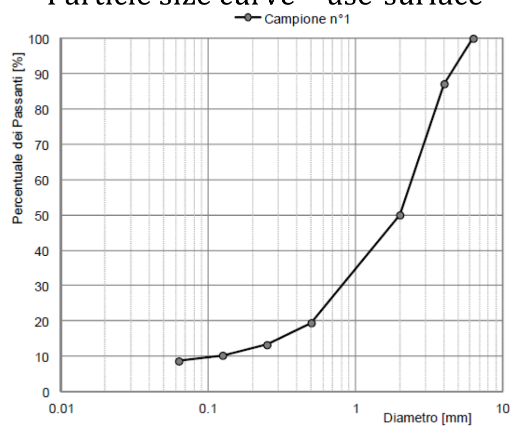
Concerning the emission of tyre/paving contact, over time it is observed a progressive decrease of the noise difference between special paving and paving reference from an initial value of 6.4 dB (A) to the measured value in the July 2012 session of 3.6 dB (A).

Concerning the noise roadside, the results show a drastic worsening of the ante/post difference. We can notice an initial difference of 9.7 dB (A) that arrives close (and higher) to 0 dB (A) as measured in August 2012 session.

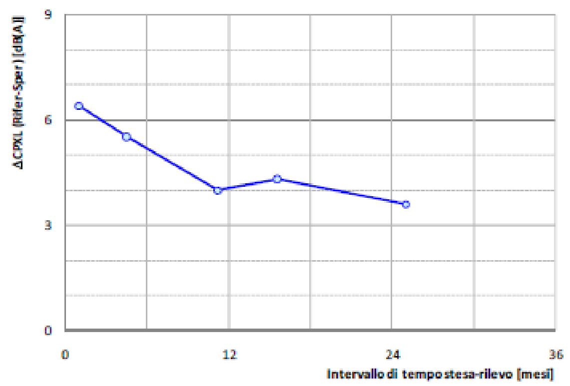
Concerning the contact spectrum emission (tyre/paving) it was not observed any significant difference compared to the spectrum of the reference paving.

Image

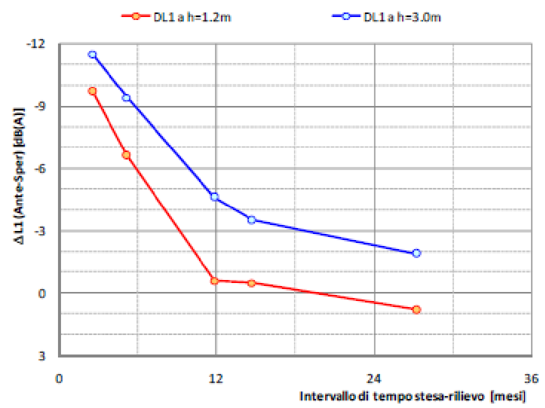
Particle size curve – use-surface



Rolling noise – CPX



Level of roadside noise – SPB



Source: Leopoldo1 Project Link: www.arpat.toscana.it/documentazione/report/progetto-leopoldo201d-relazione-finale-fase-ii-2012

1. LOW NOISE PAVINGS

Field of application: extra-urban

1.6 USE-SURFACE GAP GRADED WITH THE ADDICTION OF POLYMERS SBR/NR	**Location:** Pistoia Le Panche	**Name of the tested street** SRT 66 *Pistoiese* **Mileage:** km 53+908/54+056	**Typology of location:** mountain **Altimetry:** 670 m s.l.m.

Layers of the paving

LAYER	THICKNESS	MATERIAL
USE-SURFACE	3 cm	Use surface with bituminous mixture "gap graded with addiction od polymers SBR/NR"according to wet process
BINDER	6 cm	Binder layer with bituminous mixture mixture "gap graded with addiction od polymers SBR/NR"according to wet process
BASE	10 cm	Base layer with traditional bituminous mixture+SAMI (Stress Absorbing Membrane Interlayer)

Traffic Data	Hourly flow	Light vehicles	% Heavy vehicles
TGM	2403	2062	14.2

Rolling noise - CPX at 50 km/h

Date	Period between paving and testing [months]	Reference scenario (Srif) [dB(A)]	Experimental scenario (Ssp) [dB(A)]	Difference Srif-Ssp [dB(A)]
July 2010	1	97.5	93.3	4.2
July 2012	25	97.4	92.9	4.5

Level of roadside noise – SPB a 50 km/h

Date	Period between paving and testing [months]	Noise levels L1 at 50 km/h [dB(A)]			
		L1 a h=1.2 m	ΔL1 a h=1.2 m	L1 a h=3.0 m	ΔL1 a h=3.0 m
november-05	Ante-operam	72.6		74.1	
august-10	2	64.3	-8.3	65.4	-8.7
october-10	5	64.0	-8.6	63.9	-10.2
may-11	12	68.7	-3.9	71.8	-2.3
september-11	15	68.2	-4.4	71.6	-2.5
july-12	26	67.3	-5.3	69.8	-4.3

Low noise pavings

Use-surface "gap graded with the addiction of polymers SBR/NR"

The graded-gap use-surface are mixtures with granulometric characteristics high quality of the materials that enable to obtain good performance in terms of durability, mechanical performance and road safety.

These membranes bring a high contribution to road safety, suggesting their increased application both in construction of new paving and in use-surface makeover of existing paving.

The gap graded additives mixtures with SBR / NR polymers are non-slip use-surface of a thicknesses of at least 30mm, composed of a mixture of gravels, sands and additive (filler), hot mixed with modified bitumen and SBR / NR polymers by specific plants.

The binder used is bitumen modified with recycled rubber polymer from used tyres, incorporated in the bitumen by wet process.

This mixture, closed and totally impermeable to the underlying layers, has been studied to improve the adherence and waterproof of the underlying structure.

From the acoustic point of view, the paving, being of closed type, doesn't show any absorption noteworthy over time, unless a modest initial absorption at 630 Hz immediately disappeared, but with a clear variability of the absorption levels over time that makes a strong temporal standard deviation.

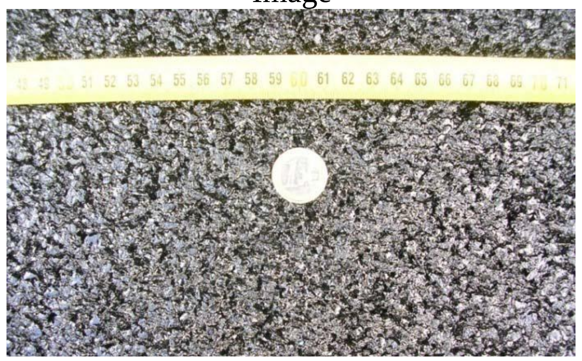
Concerning the emission of tyre/paving contact, it has been noted a trend not perfectly steady throughout time, however with differences comprised between 4.4 and 5.2 dB (A) compared to the reference and, after two years, this reduction stands of at 4.6 dB (TO).

Concerning the level of roadside noise, the results fully confirm what was seen with the CPX measurements, namely a substantial variability over time of the ante/post differences, with a large statistical fluctuation of results.

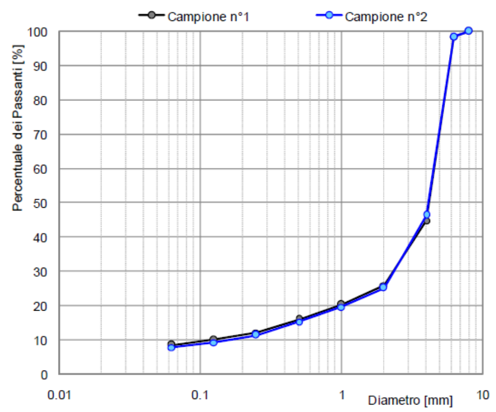
The difference of the levels measured ante/post of the index SPB L1 ranges from 3.9 (May 2011) to 5.3 dB (A) (July 2012).

Concerning the spectrum of noise frequency generated from the paving, in the case of CPX measurements, we can notice a substantial equality between the spectrum ante and post, with a preponderance of the high frequencies. While about roadside measurements, there was a substantial equality between the spectra ante and post-operam.

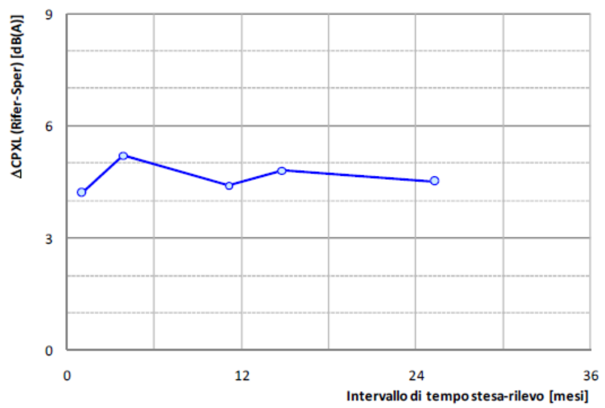
Image



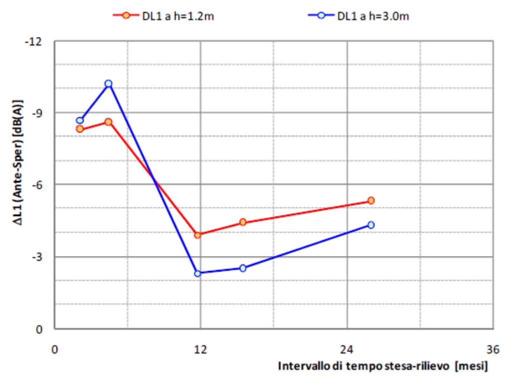
Particle size curve – use-surface



Rolling noise – CPX



Level of roadside noise – SPB



Source: Leopoldo1 Project Link: www.arpat.toscana.it/documentazione/report/progetto-leopoldo201d-relazione-finale-fase-ii-2012

2. INTERVENTIONS ON TRAFFIC REGULATION		
2.1 CHICANE/ROAD NARROWINGS		
Field of application: urban		
Advantages	- noise reduction.	
Disadvantages	- slowdown of the traffic flow with some problems connected.	
Expected results		
Theme	Effects	Source
Noise	1-2 dBA (as consequence of a speed reduction of 10 km/h)	
Air quality		
Health		

Interventions on traffic regulation

Chicane/Road narrowings

Chicanes are a type of "horizontal deflection" used in traffic calming schemes to reduce the speed of traffic maintaining a smooth traffic behaviour. Drivers are expected to reduce speed as a consequence of paying more attention to the vehicle path. The road narrowings can be an occasion for the implementation of cycle track in urban areas. From the acoustic point of view, a general speed reduction involves a consequent decrease of noise.

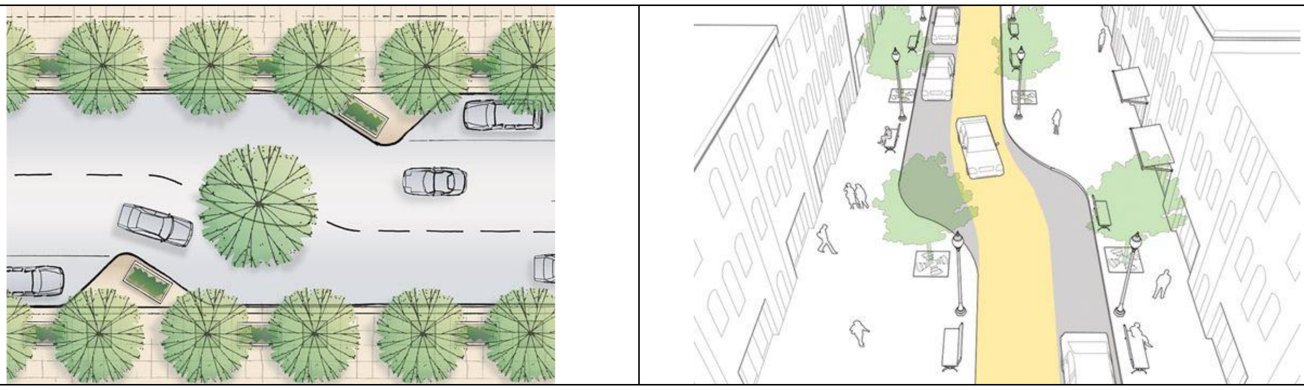


Figure: Illustration of a chicane
Source: NACTO Urban Street Design Guide

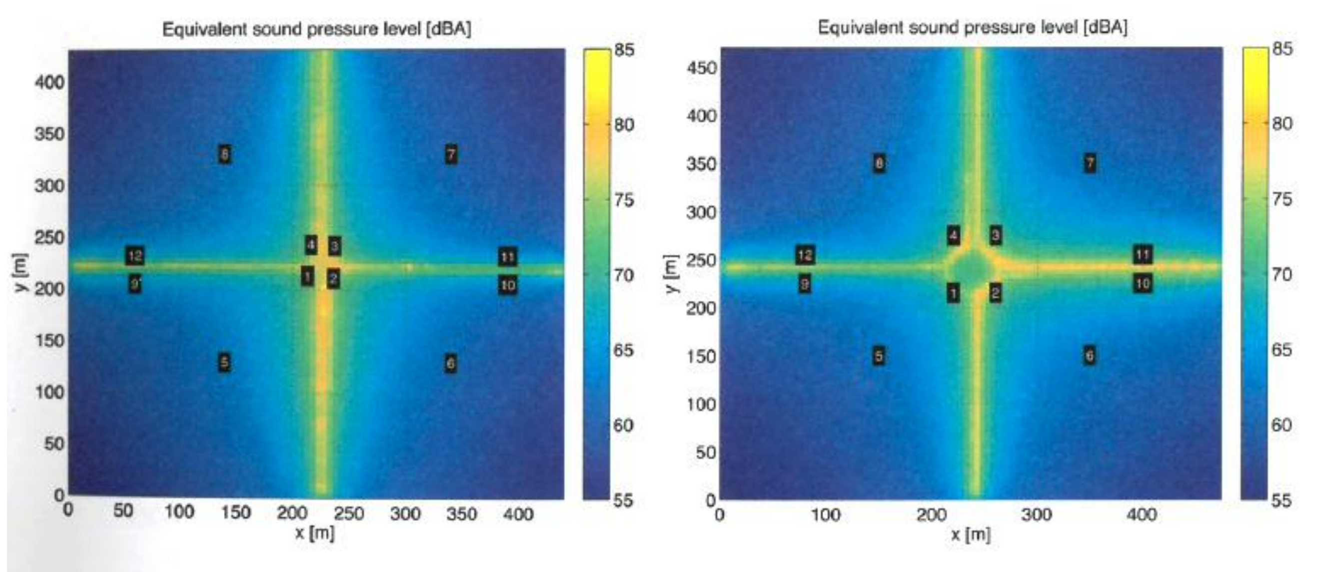
2. INTERVENTIONS ON TRAFFIC REGULATION		
2.2 ROUNDABOUTS		
Field of application: urban		
Advantages	- noise reduction; - traffic calming and del reduction of the accidents; - possibilities for heavy vehicles to change direction with a safer drive.	
Disadvantages	- no fast tracks; - more risks for motor schooters to have accidents; - move pedestrian crossing farther from the intersection.	
Expected results		
Theme	Effects	Source
Noise	about 2-3 dB(A) on roadside, next to the intersection	SONORUS Project HUSH Project (report Action 5)
Air quality		
Health		

Interventions on traffic regulation

Roundabouts

A roundabout is a particular road junction where traffic moves in one direction round a central island to reach one of the roads converging on it.
The roundabouts have found a large use in recent years in many urban and extra-urban contexts thanks to a series of strengths:
- decrease of the traveling speed in the road section where the roundabout is located;
- reduction of conflict points between vehicles and consequently decreasing of the road accidents and their severity;
- smooth traffic flow due to a complete elimination of downtime;
- reduction of noise and air pollution compared to an intersection with traffic light;
- possibilities for heavy vehicles to change direction with a safer drive;
- improve architectural aspect of the junction.

Figure: Illustration of a roundabout
Source: NACTO Urban Street Design Guide



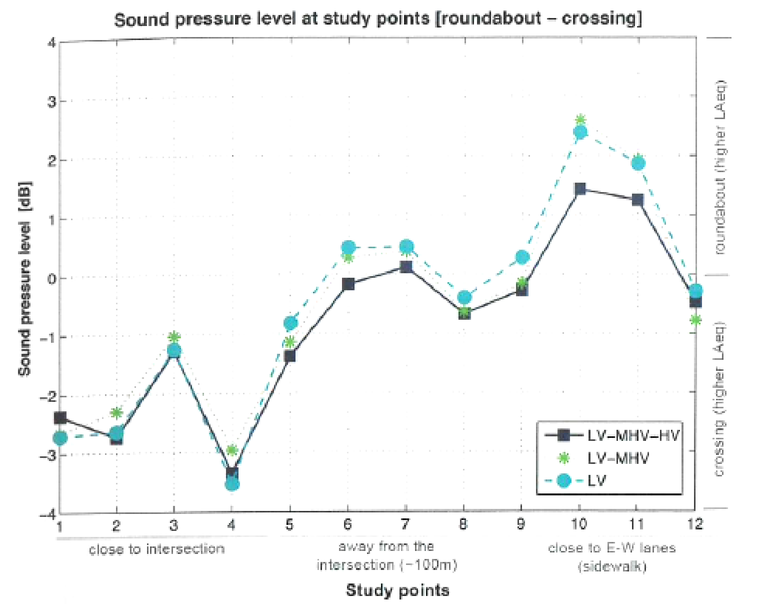


Figure: Sound Pressure Levels next to a traditional crossing and a roundabout
Source: SONORUS Project
Link: www.fp7sonorus.eu

2. INTERVENTIONS ON TRAFFIC REGULATION	
2.3 SPEED BUMPS	
Field of application: urban	
Advantages	- noise reduction; - low costs; - more safaty in the case of a pedestrian crossing.
Disadvantages	- slowdown of the traffic flow with some problems connected.; - possibility of impulsive noise if crossed at high speed or by trucks.
Expected results	

Theme	Effects	Source
Noise		
Air quality		
Health		

Interventions on traffic regulation

Speed bumps

The speed bumps are the common name for a family of traffic calming devices that use vertical deflection to slow motor-vehicle traffic in order to improve safety conditions.
The speed of a vehicle passing over a bump decreases with the height of the bump. Its height is between 5 cm to 15 cm and it can be long from less than 30cm to nearly 3 meters (often used as pedestrian crossing).
The speed bumps longer than 3 m are often called anti-speed bumps, and are often used to slow down traffic in residential neighbourhoods. The use of anti-speed humps is widespread in the world, and are most often located where the speed of vehicles traveling on the road is rather low. Each of these devices can be made of a variety of materials as asphalt, concrete, recycled plastic, metal etc.
From acoustic point of view, the speed bumps are very effective in keeping low the vehicles speed and consequently in reducing the vehicle noise emissions. Nevertheless, if crossed at high speed or by trucks, it can cause a significant impulsive noise.

Figure: Illustration of a speed bump
Source: NACTO Urban Street Design Guide

Figure: example

Figure: example

Figure: Speed bump for pedestrian crossing - Area Brozzi- Quaracchi (Firenze)
Source: HUSH Project
Link: www.hush-project.eu

2. INTERVENTIONS ON TRAFFIC REGULATION	
2.4 SAFETY ISLANDS	
Field of application: urban	
Vantaggi	- traffic calming; - more safety for pedestrians crossing the road;
Svantaggi	Otherwise the island can become a dangerous obstacle if there isn't a clear indication.
Expected results	

Theme	Effects	Source
Noise		
Air quality		
Health		

Interventions on traffic regulation

Safety Islands

The safety islands are installed on a busy or wide road to assist pedestrians to cross the road in two stages. They are a very useful structure for the safety of pedestrians crossing the road. They allow pedestrians to concentrate on traffic from one direction at a time.
Road permitting, the safety island should have a width of about 2.00 meters, to protect even bicycles and prams.
Safety islands with less width can be useful and efficient especially as an indication of traffic calming. In fact, safety islands are also effective as possible structures of "traffic calming" when:
- they are built in series;
- they are installed in conjunction with a pedestrian crossing (zebra).

In this case, islands and the zebra jointly are a strong and clear indication that the road is high and extensive presence of pedestrians. The drivers of vehicles have to drive with low rate of speed because they have to "live" with pedestrians. In addition, safety islands prevent overtaking, especially of motorcycles. Safety islands are more efficient when accompanied by an adequate road sign that announces in advance its presence (about 40-50 meters). Otherwise the island can become a dangerous obstacle.



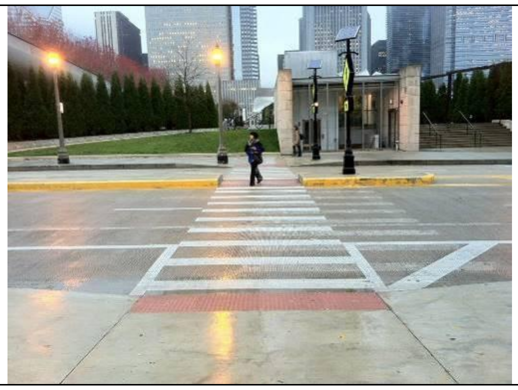



Figure: examples of safety islands

2. INTERVENTIONS ON TRAFFIC REGULATION		
2.5 ELECTRONIC DEVICES FOR SPEED CONTROL		
Field of application: urban and extra-urban		
Advantages	- noise mitigation	
Disadvantages	- sometimes increasing of the accidents	
Expected results		
Theme	Effects	Source
Noise		
Air quality		
Health		

Interventions on traffic regulation

Electronic devices for speed control

Electronic devices for speed control include all systems that allows the speed control of vehicles. They can be fixed or movable.

The most common types are **speed cameras** and **tutor systems** (SICVE). The SICVE (Information System for Speed Control) is used mainly on highways and detects the speed average of vehicles.

Other systems for speed control are **intelligent traffic lights** for limiting the traveling speed of the vehicles. Through a speed measure system placed close it, the traffic light recognizes the vehicle passing with too high speed and activates the procedure for blocking it.

Other devices are **traffic and speed bollards** places close to vertical speed limit signals. They work as psychological deterrents because they allow to read the speed of the vehicle in real time.

			
Figure: example of a speed camera	Figure: example of a tutor system for speed control	Figure: example of an intelligent traffic light	Figure: example of a traffic and speed bollard

3. STRATEGIC ACTIONS		
3.1 URBAN TRAFFIC PLAN		
Field of application: urban		
Advantages	- urban requalification; - reduction of problems connected to traffic	
Disadvantages	- preliminary study of the mobility and of noise mitigation	
Expected results		

Theme	Effects	Source
Noise		
Air quality		
Health		

Strategic actions

Urban Traffic Plan

The Urban Traffic Plan (PUT, art. 36 of Codice della strada) is required for agglomerates with more than 30.000 inhabitants and it consists of interventions for improving the conditions of traffic, pedestrians and public vehicles.

The study of the mobility is connected to noise mapping. A global valutation of urban traffic plan can reduce the noise exposure of the inhabitants.

Some interventions inclused in the urban traffic plan are: regulation of the entrance of vehicles in the city, distribution of traffic flow also in extra-urban roads.

3. STRATEGIC ACTIONS		
3.2 PUBLIC ELECTRIC VEHICLES		
Field of application: urban		
Advantages	- noise reduction and improvement of air quality.	
Disadvantages	- low transport capacity; - logistical needs that to recharge the batteries.	
Expected results		

Theme	Effects	Source
Noise	Depends on the composition of the traffic flow before and afetr the introduction of electric vehicles	
Air quality		
Health		

Strategic actions

Public electric vehicles

The electric buses appear, among the electric road vehicles, the fastest growing types, despite the low transport capacity of these vehicles and logistical needs that characterize them as the need to recharge the batteries.
The emerging logic is set up service networks in historic city centres closed to private traffic, sometimes the public electric vehicles don't replace the existing public services but integrate them. They allow a great noise reduction, but the high cost of vehicles, e could definitely discourage invest in this sector.

3. STRATEGIC ACTIONS		
3.3 30 km/h ZONES		
Field of application: urban		
Advantages	- improvement of road safety; - reduction of the acceleration phase, with consequent decreasing of the fuel consumption and pollutant emissions; - reduction of the traffic volumes; - noise reduction; - incentive to walk or bike avoiding the use of the car.	
Disadvantages		
Expected results		
Theme	Effects	Source
Noise	30 km/h zones could create a noise reduction of 3-4 dBA inside the 30 km/h area, connected to speed reduction of light vehicles, but it depends by scenario.	
Air quality		
Health		

Strategic actions

30 km/h zones

30 km/h zone is a strategy for traffic calming in urban road network. It was introduced in Italy in 1995 within the Directive on Urban Traffic Plan (PUT).
As the name suggests, the 30 km/h zone is an area where the speed limit for urban roads is fixed on 30 km/h instead of the normal 50 km/h allowed in urban areas.
The lower speed limit allows a better coexistence among cars, bicycles and pedestrians.
The 30 km/h zone can be implemented in every city if there are streets with speed limits not exceeding 50 km/h. If there are roads with a speed limit at 70 km/h, it is necessary to create areas with speed limit at 50 km/h.
In 30 km/h zone, the projects should provide also interventions in favour of pedestrians and cyclists such as the reduction of motor traffic space in favour of the space reserved to the cycle paths and sidewalks, and the creation of areas used for social purposes.
To help reducing the speed of motor vehicles is necessary to provide a series of structural measures such as optical and/or acoustic retarders, bumps, roundabouts and traffic islands without creating obstacles to emergency vehicles.

Figure: examples of a 30km/h zone

Figure: examples of a 30km/h zone – area Brozzi-Quaracchi (Firenze)
Source: Hush Project
Link: www.hush-project.eu

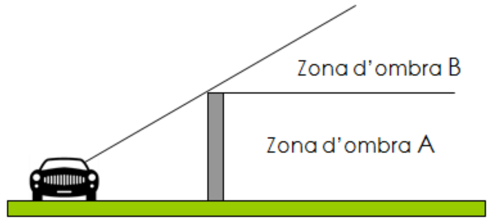
4. NOISE BARRIERS

4.1 TRADITIONAL NOISE BARRIERS

Field of application: urban and extra-urban

Advantages	- noise reduction
Disadvantages	- visual impact; - structural complications and maintenance costs.

Expected results

Theme	Effects	Source
Noise	14 dB for receivers in zone A; 7 dB for receivers in zone B; 0 dB for receivers outside zone Anad B.  	D.M. 29/11/2000
Air quality		
Health		

Noise barriers

Traditional noise barriers

The barriers allow the reduction of the sound pressure that reaches the receiver. In fact, the barrier is interposed between the source and the receiver in a way that the sound waves reach it only by diffraction path.
From an acoustic point of view, the barriers can be divided into reflecting and absorbent types.
The effectiveness of the barrier depends on:

- location: it is appropriate to keep it as close as possible to the sound source;
- height, such as not to allow the visibility of the source from the receptors;
- length: to reduce as much as possible the lateral diffraction effects which produce a reduction of attenuation;
- thickness: it reduces the amount of diffracted energy that reaches the receptor;
- sound insulation: it must be such as to make insignificant the contribution of transmitted energy compared to the diffracted one.
- sound absorption: the sound absorption barriers are generally used to prevent the reflection of sound.

Besides acoustic issues, when an acoustic barrier is installed in a specific place, the esthetical aspects and landscape impact should be considered as well.
In general, panels of a noise barrier can be of different materials such as wood, transparent materials, concrete, metal, earthnware, strengthened ground, plan covered, etc…




Figure: examples of noise barriers

4. NOISE BARRIERS		
4.2 LOW BARRIERS		
Field of application: urban		
Advantages	- noise reduction - low visual impact	
Disadvantages	- maintenance costs	
Expected results		
Theme	Illustrations of scenarios considered	Source
Noise		SONORUS Project
Air quality		
Health		

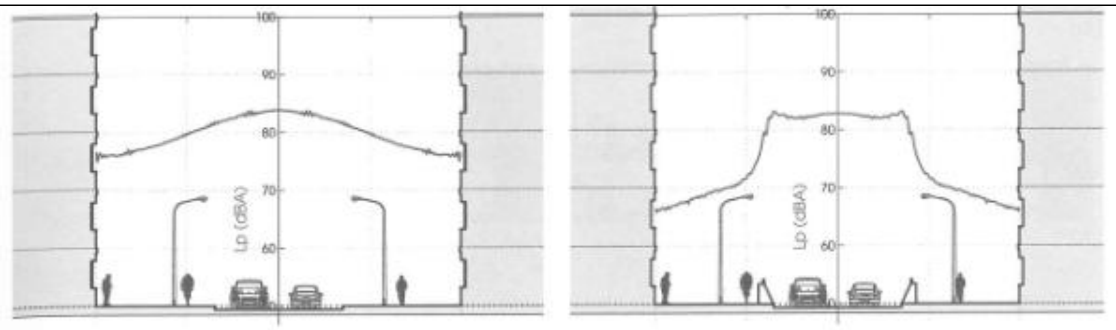


Figure 1 - Reduction of noise level at pedestrians by a low inclined barrier

Figure: Noise reduction of low and inclined barriers for pedestrians
Source: SONORUS Project

Noise barriers

Low barriers

In the urban context, motorized traffic and pedestrians or cyclists are often found in the same street canyon. Small barriers have little effect on the exposure of façades flanking the street except for the lowest floors, yet they can reduce the level near pedestrians if shaped correctly.
The main results of SONORUS Project on some street cases can be summarized below:
- a small vertical barrier reduces noise levels with more than 4 dB(A) for pedestrians;
- inclination of a low barrier additionally reduces 3 dBA for pedestians (8 dBA in total);
- 30 degrees inclination is the most beneficial for this canyon dimensions;
- different absorbation gives reduction of pedestrian exposure within 4 dBA range;
- the most efficient face to place the absorption is the source side (S2.3) (additionally 2 dBA);
- the least efficient face is the receiver side S2.2;
- the addition of absorption on the top of the barrier (in S.2.2 or S.2.4) reduces additionally 1 dBA for pedestrians, despite the small surface;
- the maximum reduction achieved compared to the non-barrier case is of nearly 9 dB(A) with all surfaces absorbent (S2.5).

However, the addition of absorbtion on an inclined low barrier has different effects than on a vertical one:
- different absorption treatment for an inclined low barrier varies by 2 dBA;
- the most efficient faces for adding absorption are receiver side and top;
- the addition of absorption on the source side has no additional effect for the inclined barrier case;
- absorptive wainscot does not additionally reduce noise for pedestrians.

List of Annexes
of the *Abacus on operational context on Noise Low Emission Zone*

- Legal and Environmental framework for Noise LEZ introduction
  Annex 1 of Abacus on operational context on Noise Low Emission Zone

- Operational context: Noise Monitoring Systems
  Annex 2 of Abacus on operational context on Noise Low Emission Zone

- Operational context: Air Quality Monitoring Systems
  Annex 3 of Abacus on operational context on Noise Low Emission Zone

- Operational context: Health indicators
  Annex 4 of Abacus on operational context on Noise Low Emission Zone

- Operational context: interventions and expected effects on air quality, noise and health
  Annex 5 of Abacus on operational context on Noise Low Emission Zone

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