Footprint analysis concerning noise: approaches, tools and opportunities

Michele GORETTI[1]; Franco COTANA[2]

[1, 2]University of Perugia - CIRIAF, Italy

ABSTRACT

A methodology to control noise through footprint analysis is proposed. It involves determining the noise contribution produced by significant sources in their surroundings, such as transport infrastructures (not just aircraft and airport), industrial sites and other technical facilities, or by individual sources throughout their life cycle, including motor vehicles, machinery, equipment and the typical devices to which we are exposed during working or leisure time. The main acoustic parameters must be analysed: measurement and simulation of noise indicators, comparison with the limits imposed by legislation and calculation of any overruns are expected. The paper illustrates the technical issues of the research concerning noise footprint. The aim is to provide scientific and technical support to the implementation of noise abatements and environmental sustainability. The scientific value of the research consists in the study of approaches, tools and opportunities to convert noise descriptors in population and soil units referred to the exposed number of inhabitants, by quantifying the areas where noise limits are not exceeded as well as a kind of compensation to allow sustainable development. Therefore noise footprint is not merely a graphical representation of noise contours on maps. As an example of application of footprint analysis to noise, a pilot project and the study of patented solutions are in progress.

Keywords: Noise, Footprint, Sustainability I-INCE Classification of Subjects Number(s): 52.9

1. INTRODUCTION

Environmental noise is acknowledged as a serious problem with significant health impacts. Actions should be considered to reduce the number of people affected by harmful noise levels in built up areas and workplaces. International, national and local initiatives are being developed and implemented to limit noise arising from human activities, relying on the quantification, assessment, monitoring, reporting and verification of sound emissions and abatements. New and more effective tools to reduce noise must be explored and implemented where high exposure occurs.

Ecological, carbon and water footprint are similar concepts which show the pressure of humans on the environment, based on common methods which may be extended to other components. The formulation may be expanded to consider noise.

The paper focuses on footprint analysis and proposes procedures to extend it to noise topics. Different ways to conceive footprint analysis as regards noise are illustrated, depending on the source type: in fact, in principle the methodology can be applied with peculiar approaches and specific features to all noise sources.

Different assessment methods may be distinguished in order to express specific noise impacts, in particular when considering the major noise sources, such as transport infrastructures and industrial facilities, or the noise due to organizations (sound emissions generated by every human activity), projects (actions to prevent and reduce noise) and products (machinery and the production of every good and service).As a result, noise footprint analysis may be applied both to agglomerations and to individual sources.

[1] michele.goretti@unipg.it
[2] franco.cotana@unipg.it

2. DEFINITION

Noise footprint is a well established concept in airport noise control. An aircraft noise footprint is a graphical illustration of the area affected by the noise levels produced by a specific aircraft type: it is used to specify shape and area of combined SEL contours during landing and takeoff. Each aircraft type has its own noise footprint and the maximum sound level experienced on the ground as the aircraft flies over is shown in decibels (dB) as different noise contours.

In principle this concept may be extended to all noise sources. However, if noise footprint were limited to express noise levels nearby and over an area, it would not be different from noise mapping. The usefulness and originality of the proposed approaches consist in representing on the maps the areas where the thresholds set in the acoustic zoning as quality limits are exceeded or not exceeded, showing the extent of differences with various colors.

Footprint analysis is a comprehensive and multidimensional tool accounting for human pressures and consumptions: the noise footprint aims at measuring the balance of noise emission and abatement related to an individual, a product, a project, an organization, a population or a nation.

3. AIM

The aim of noise footprint determination is to express the contribution of noise to environmental quality and to assess perspectives of sustainable development in the general framework of the overall environmental footprint.

Noise footprint is intended:

- to verify not only the respect of the limits, as noise maps, but also the quality of the acoustic environment through the extent of the differences over or under the limits;
- to estimate the overall context, including the number of exposed persons and the type and density of activities on the site.

In particular, approaches based on the application of footprint analysis and life cycle assessment tools to environmental noise as the single impact category are expected:

- to facilitate the tracking of performance in reducing noise emissions;
- to identify opportunities for noise decrease and environmental sustainability;
- to change consumer behaviour which could contribute to reduce environmental noise;
- to supports comparability of products as concerns noise;
- to facilitate the evaluation of alternative product design, sourcing options, production and manufacturing methods to reduce noise;
- to provide information to decision makers in order to improve the acoustic climate.

4. DESCRIPTORS

As regards noise, there are no matter flow and no mass emission: noise, as well as vibration, optical radiation and electromagnetic fields, is just a physical agent. As a physical agent, noise is a source of energy which propagates in form of acoustic waves across elastic media (air, water, soil etc.).

This is a significant difference compared, for example, to carbon footprint, were GHG emissions in one site can be offset by equivalent removals elsewhere. questions about.

Regarding the indicators to be used to quantify and communicate results, it should be noted that frequency, sound pressure and power, duration and time distribution are the most important characteristics of noise which may influence human health.

Generally, in footprint analysis many different data are converted into a common and equivalent single unit indicator. As concerns noise, the common unit could be average equivalent sound pressure level L_{Aeq} given in dB(A). Depending on noise sources and their variability along time and space, noise equivalents shall be articulated and expressed in terms of different indicators.

According to the European Directive 2002/49/EC (1), day-evening-night time noise indicator L_{den} and night time noise indicator L_{night} may be selected as reference common units, as well as other useful descriptors, where needed. Noise limit values, in fact, are established by national legislations for noise indicators which may be different from L_{den} and L_{night}, such as:

- L_{day}, as noise limits in many countries don't provide a specific evening time noise indicator $L_{evening}$;
- L_{VA}, based on sound exposure level SEL or L_E, concerning airport noise in Italy.

L_{day}, $L_{evening}$ and L_{night} are the A-weighted long term average sound levels determined throughout

the day, evening and night periods of a year. L_{den} allows to assess the degree of community noise annoyance and L_{night} is highly correlated with sleep disturbances inflicted on the community.

The values of noise footprint indicators may be obtained by measurements or calculations. As each state may apply the national evaluation method until common tools are issued (1), the noise metric adopted for the acoustic territorial zoning should be consider to define noise footprint.

Noise equivalent units could allow to compare on a time and space basis the sound emissions of different sources. Noise footprint descriptors shall take into account also the percentages of population and surface area affected by noise exceeding the established limits, through the integration of statistics and demographic analysis techniques as well as updated and geo-referenced official data (2).

5. REFERENCE VALUES

According to national Law n. 447/1995 on noise pollution, in Italy quality values are the noise targets to be achieved in the short, medium and long term by the available technologies and methods concerning noise abatement to fulfill the objectives of human protection against noise. Quality noise values were established (DPCM 14 November 1997) for day time (from 6:00 to 22:00) and night time (from 22:00 to 6:00) in the different classes of the acoustic zoning. In a perspective of sustainable development, it seems appropriate to assume quality values as the limits to determine noise footprint.

Regarding transport infrastructures, specific buffer zones, indicators, limit values and divisions of day periods were established by national Decrees on transport noise to manage road networks (DPR 30 March 2004, n. 142), railways (DPR 18 November 1998, n. 459) and airport areas and operations (DM 31 October 1997).

6. APPROACHES

Depending on the sources to be examined, the approaches to noise footprint analysis may differ, but generally the principles of environmental footprint and life cycle assessment (LCA) seem to be a good reference.

Noise concerns organizations, projects and products and it occurs throughout their activities and life cycle, from raw material acquisition through production, use and end of life treatment (from cradle to grave), as well as greenhouse gases (GHGs).

The proposed approaches respect a common scheme (Figure 1), based on international standards concerning environmental managing (3), labelling (4) and declaration (5), but they differ in the specific level or source type.

The operative method refers to GHG management framework, composed by ISO 14064-1 (6), ISO 14064-2 (7), ISO 14064-3 (8) and ISO/TS 14067 (9).

The basic principles of the methodology for noise footprint quantification and communication shall be relevance, completeness, consistency, coherence, accuracy, transparency, conservativeness, avoidance of double counting, participation, fairness, independence, ethics and professionalism.

Object, purposes, content and methodology of noise footprint analysis shall be identified and, where possible, quantified. The core issue of the analysis consists in the design and development of the noise inventory. The inventory phase is based on the study and assessment of noise impact and it involves:

- the definition of the system boundaries, which includes the identification of unit processes, functional units, noise sources, cut-off criteria and exclusions, relevant “noise sinks” (having sound absorption and insulation properties), direct and indirect emissions and abatements and the determination of the baseline scenario;
- the quantification of noise, which consists in the selection of the quantification methodology, the impact category indicators and the characterization models, the allocation of inputs and outputs, the collection of noise activity data, the choice or development of noise emission or abatement factors and the calculation of noise emissions and abatements.

Depending on the studied object, noise footprint analysis may be set on:

- a relative approach, focusing on a facility, an activity or a functional unit;
- an iterative approach, consisting in goal and scope definition, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA) and interpretation;
- a scientific approach, preferring natural science (such as physics, chemistry and biology), other scientific approaches (such as social and economic sciences) or relevant and valid

international conventions.

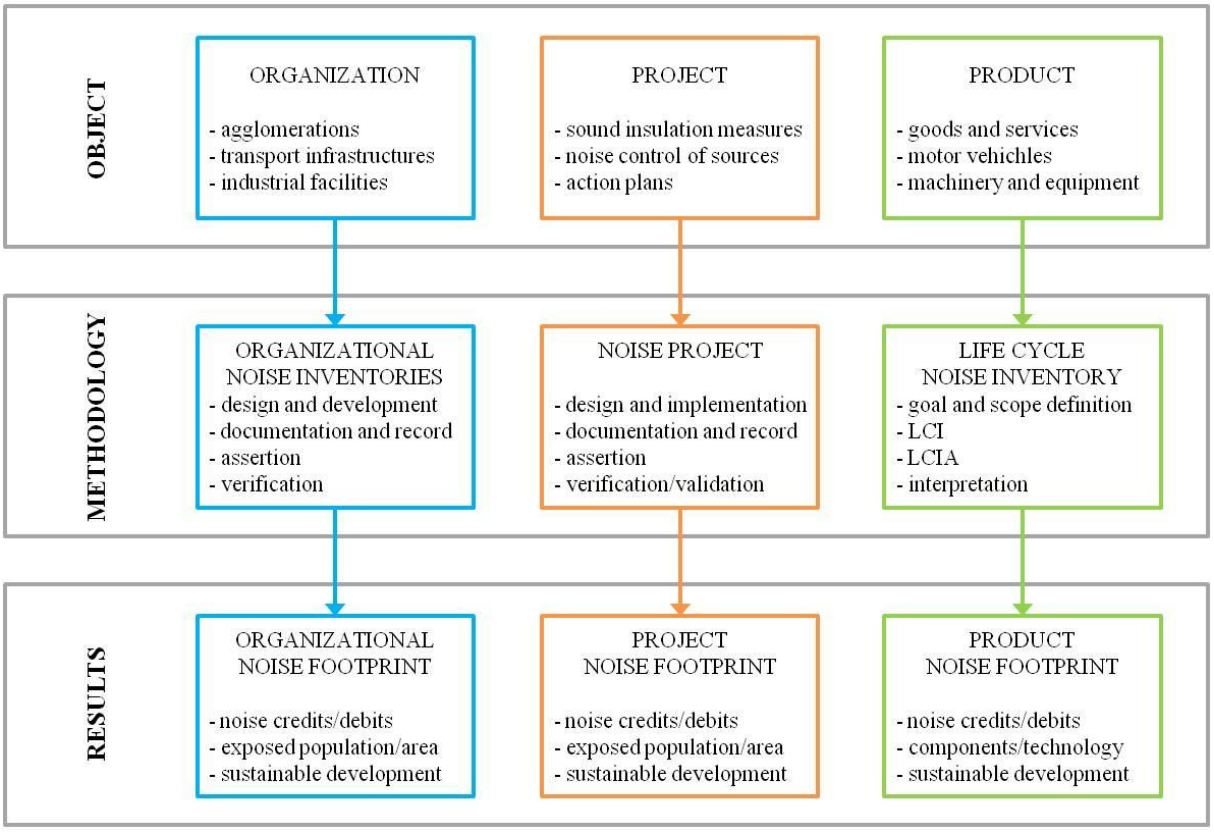

Figure 1 – Noise footprint: scheme

Also other requirements shall be expected, such as directed actions to reduce noise emissions or increase noise abatements, base year noise inventory, assessment of noise data and reduction of their uncertainty, quality management concerning document retention, record keeping and report planning, monitoring and estimation activities, information system control, noise assertion and facts discovered after the validation or verification.

Finally, approaches to noise footprint analysis should focus on:

- noise inventories at the organization or company level, as well as combinations of noise sources, such as agglomerations, transport infrastructures and industrial facilities. They may include:
  - requirements for determining noise emission boundaries, quantifying noise emissions and abatements of the organization, identifying specific company actions or activities to improve noise management;
  - requirements and guidelines on inventory quality management, reporting, internal auditing and responsibilities of the organization for verification activities;
- activities intended to cause noise emission reductions or noise abatement enhancements at the project level, including sound insulation measures, noise control of sources, acoustical planning and action plans. They may concern:
  - principles and requirements for determining project baseline scenarios as regards noise topics;
  - principles and requirements for monitoring, quantifying and reporting the performance of the project or activity relating to the baseline scenario;
  - guidelines and basis for the projects to be validated and verified;
- verifying noise inventories and validating or verifying projects concerning noise topics. They may include:
  - description of the process for noise related validation or verification;
  - specification of components such as validation or verification planning,

assessment procedures and the evaluation of the organization or project assertions about noise;

- noise under a life cycle perspective at the product level, including any goods and services as well as individual noise sources, such as motor vehicles, machinery and equipment. It may regard:
  - principles, requirements and guidelines for the quantification of total or partial noise footprint of products, based on noise emissions and abatements during their life cycle;
  - principles, requirements and guidelines for the communication of the noise footprint of a product to the intended audience on the basis of a noise footprint study report that provides an accurate, relevant and fair representation of the noise footprint analysis.

Actually the following steps are needed:

- setting of noise limit values for day, evening and night time, depending on the observed noise source or sources and the acoustic zoning, as well as specific regulations (e.g. noise protection of workers at workplaces);
- measurement and/or calculation of noise levels in the selected area, to be processed by noise modelling and mapping tools;
- identification of conditions and sites featuring positive or negative differences between obtained noise levels and limit values, taking into account significant parameters, such as land use and density of exposed population.

Any approaches or decisions taken have to be explained and justified.

The final report shall include:

- the procedure adopted to calculate the noise footprint;
- the results of the analysis;
- the feasible measures identified to reduce sound emissions in the life cycle and to "neutralize" noise (in those areas, processes or functions characterized by noise surplus or deficit compared with the appropriate limit values;
- the communication strategy for public dissemination.

7. TOOLS

7.1 Noise Regulations and Legislation

In the EU the Environmental Noise Directive 2002/49/EC (1) aims at establishing a common approach to avoid, prevent and reduce the effects of human exposure to noise sources. The main purposes are:

- the evaluation of exposure to environmental noise, through noise mapping, by using common noise indicators;
- the information of the public on environmental noise and its effects;
- the adoption of action plans based on noise mapping results.

The Environmental Noise Directive provides to develop the existing measures concerning noise emitted by the major sources (road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery) and to harmonize noise indicators and environmental noise evaluation methods depending on the noise sources. Actually no deadline or timetable was provided to establish common noise assessment methods for the determination of the noise indicators. Until the harmonized methods are available, the Directive establishes interim methods to be used (10).

As regards noise at workplace, the aim of the Noise Directive 2003/10/EC (11) is to define minimum requirements for the protection of workers from risks to their health and safety arising from exposure to noise.

7.2 Noise Models, Databases and Registers

The available software, mathematical models and calculation methods concerning environmental noise need to be continuously updated, improved and developed, taking into account more exactly the description of the individual sources, their variability and the influence of weather conditions and atmospheric absorption on propagation. Software tools can help to manage all data involved in noise modelling. Waiting for harmonization, the Environmental Noise Directive (1) recommends the

following methods:

- ISO 9613-2 for industrial noise;
- ECAC.CEAC Doc. 29 for aircraft noise;
- the French national method NMPB-Routes-96 for road traffic noise;
- the Netherlands national method Reken en Meetvoorschrift Railverkeerslawaai ’96 for railway noise.

Noise inventory tools are necessary to store, use and assess sound emission data from a large number of sources. Consistency and traceability of data used in noise assessments are also needed, in order to select which sources shall be included in the inventory and which associated data are available, in order to test project scenarios, to investigate the effect of new installations in low sound emission zones and to reduce noise in productive areas and buffer zones of transport networks. The use of a comprehensive database of noise sources is highly recommended: sound emission data must be integrated to introduce corrections and source types currently present.

Finally, the regional agency for environmental protection ARPA Umbria, in collaboration with the Industrial and Environmental Technical Physics area of the Department of Engineering at the University of Perugia (Umbria, Italy), developed an innovative on-line register of noise sources distributed throughout Umbria Region (12). Basically, the register consists of a database and maps. The database collects information featuring different categories of sources (temporary, commercial, service and productive activities, road, railway and airport infrastructures) and the related acoustic climate to qualify the relevant area and the involved population (13).

Noise models, databases and registers are fundamental to determine noise footprint. providing a support for life cycle assessment and strategic noise mapping. The best practices and techniques to develop and maintain these tools shall be implemented.

7.3 Noise Mapping

The aim of noise mapping consists in the illustration of data on an existing or predicted noise situation in terms of a noise descriptor, showing the breaches of any relevant limit value, the number of people affected or the number of dwellings exposed to certain values of a noise indicator in a specific area (1).

Strategic noise maps are designed for the overall assessment of noise exposure in a given area due to different noise sources (roads, railways, airports and industrial sites, including harbours) or for overall predictions for such an area (agglomerations) (1).

Noise contours on the maps depend on several factors, including the number and type of sources, the period of the day, the way and how frequently they operate: significant changes to the noise pattern may be caused by variations in any of these factors over a long time.

Noise maps and strategic noise maps may be presented in the form of graphs, numerical data or records in electronic format. They provide information and data for action plans and noise footprint analysis to manage noise issues and effects. Data about environmental noise levels should be collected, matched or reported in accordance with comparable criteria, so the use of harmonized indicators and evaluation methods is recommended.

7.4 Acoustic Zoning

In Italy the acoustic zoning (national Law n. 447/1997 and Decree DPCM 14 November 1997) classifies the territory of a Municipality in six homogeneous areas, related to different density of population, activities and use conditions. They are characterized by different noise limit values, given in terms of L_{Aeq} and expressed in dB(A), on two periods, referred to day time (6:00-22:00) and night time (22:00-6:00). In addition to noise emission and input limits, quality values are provided (Table 1).

The above mentioned limit values are referred to all noise sources, except for transport infrastructures. The acoustic zoning maps show the buffer zones close to roads, railways, airports etc., with a width defined by the national Decrees on transport noise, where specific descriptors must respect certain limits, referring exclusively to the noise emitted by the infrastructure and usually higher than the ones set by the acoustic zoning.

Table 1 – Acoustic zoning: quality values defined by Italian decree DPCM November 14, 1997

Acoustic zoning class	Quality value L_{Aeq}, dB(A)	
	day	night
Class I Particularly protected areas	47	37
Class II Areas mainly dedicated to a residential use	52	42
Class III Mixed areas	57	47
Class IV Intensive human activities areas	62	52
Class V Mainly industrial areas	67	57
Class VI Exclusively industrial areas	70	70

Areas included in Classes II, III and IV are assigned taking into account the following settlement characteristics:

- density of population;
- density of commercial and service activities (such as offices);
- density of handcraft or industrial activities (such as factories);
- volume of road traffic.

Quality values established by acoustic zoning constitute the main reference for noise footprint quantification and give a fundamental contribution to actions and decisions.

8. OPPORTUNITIES

8.1 Noise Offsetting and Credits

The comparison between noise footprint and noise maps can identify the areas able to support the introduction of additional noise sources, in compliance with acoustic zoning classes and their quality values. As a result, noise footprint can give an immediate overview of areas or sources featuring noise debits and credits compared to quality targets.

A market for “noise units” and “noise offsetting”, as conceived for GHGs, would be a nonsense. Instead, noise debits must be reset by appropriate action plans, while noise credits are useful to select potential areas for sustainable development, where additional services or production activities (handcraft, commerce or, where possible, industry) could be installed, to be sized in order to match the acoustic class limits. Generally, excluding particularly sensitive and protected areas (Class I), the new interventions may interest any other acoustic zoning classes.

Sound emissions can’t be completely cancelled. Due to the lack of mass flow, credits may be awarded to noise sources (organizations, projects and products) as a compensative criterion depending on the use of best available technologies and engineering solutions to mitigate noise, whose size shall be based on the acoustic performance respecting standards and legislation.

In the case of noise footprint, credits shall express the noise capacity of an organization, a project or a product and consequently the magnitude of the perspectives for sustainable development in areas affected by noise.

8.2 Noise Reduction and Abatement

When applied to a specific product, noise footprint refers to the study of noise inputs along the different steps in the production system.

The individual parts of products and noise sources, such as motor vehicles, equipment and machines, as defined by the European Machinery Directive 2006/42/EC (14), must be produced and connected according to specific regulations and criteria for type approval, in order to reduce sound emissions.

The selected technologies and components, the noise sources involved in the various stages of the production process, their contribution to noise generation and the actions and programs implemented to abate noise applied shall be assessed in the noise footprint analysis. Any technical or technological innovation within the organization activity, the project development or the product life cycle, such as patents, must be specified. Processes and actions intended to produce goods and services without increasing the environment noise should be preferred and rewarded.

In workplaces proper and regular maintenance of machinery and equipment, acoustic insulation and soundproof techniques are essential to prevent sources to become noisier, to improve safety levels for workers and to achieve compliance with the legislation concerning hand-arm and total body vibration (11).

Noise footprint analysis may be a good practice guidance, compliant with relevant legislation and standards.

8.3 Application

Noise measurements and calculations may be integrated with acoustic zoning to determine the areas where noise levels are lower than the quality values, so they allow the allocation of additional activities in compliance with the acoustic zoning class.

As a case study, the acoustic zoning plan of the Municipality of Perugia was studied and an integrated approach to noise footprint analysis according to the above described criteria is ongoing. Data from noise mapping and noise sources registers were collected and are available to make assessment in the general framework of footprint analysis.

The estimated percentages of surface area and population in the different classes, according to the acoustic zoning of the Municipality of Perugia (15), are shown in Table 2.

Table 2 – Acoustic zoning of the Municipality of Perugia (Italy): percentages of surface area and population

Acoustic zoning class	Surface area, %	Population, %
Class I	12.0	4.7
Class II	30.0	23.7
Class III	52.0	57.0
Class IV	3.5	12.5
Class V	2.3	2.1
Class VI	0.2	0.0

The most sensitive areas, having the lowest and most precautionary noise limits, are classified as particularly protected (Class I) and mainly dedicated to a residential use (Class II): they cover about 42% of the surface area and 28.5% of the inhabitants. Low presence of commercial activities is allowed only in Class II, whereas handcraft and industrial activities are not admitted.

Approximately 52% of the municipal area is assigned to Class III (mixed areas,) associated with the majority of the population (57.0%). A percentage equal to 12.5% of the municipal population lives in Class IV (intensive human activities areas), characterized by the highest limit values as regards the areas with dwellings.

Overall, Classes II, III and IV group 93.2% of the resident population of the Municipality of Perugia.

The analysis of statistic, demographic and economic data shows that in the examined territory some districts are characterized by absence of population and little activities. Noise mapping results and quality values of the acoustic zoning classes are being compared to assess the noise footprint of the available areas. Figure 2 shows two sites where noise footprint analysis offers opportunities for sustainable development and environmental noise management: patented solutions may be customised to the specific case study by using noise models, databases and registers tools.

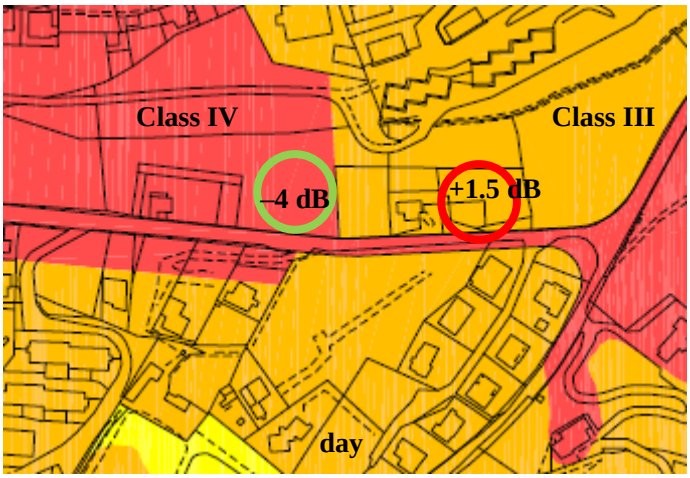

Figure 2 – Noise footprint: application

9. CONCLUSIONS

Due to the physical nature of sound and the variety of noise sources, different approaches, tools and opportunities may be identified in applying footprint analysis to noise.

We may distinguish between:

- noise footprint of products (goods and services), which concerns the production and/or involves the use of noise sources (motor vehicles, machinery and equipment);
- noise footprint of projects (to abate noise) or organizations, including combinations of noise sources affecting a specific area, such as agglomerations, transport networks and industrial facilities.

Sites, components and technologies which are available to the purposes of sustainable development, as regards noise, may be identified by noise footprint analysis.

At present, however, databases and software implement only energy and mass related criteria, so the creation of noise inventories and the verification/validation processes may be very difficult. Therefore, existing inventory databases need to include sound emissions of the different known noise sources, to be expressed in terms of shared and common indicators in order to allow comparisons.

The conversion of average equivalent sound pressure levels (dB(A)) in equivalent units which may be added in a more simple way, such as energy (J) or power units (W), doesn't seem to be useful to explain the results of noise footprint analysis. Moreover, the time basis indicator in noise equivalent units shall be integrated by a site basis descriptor, accounting for the density of exposed population and the land use. Characterization factors concerning noise may be also defined and applied.

Regarding products, the use of appropriate technical solutions and soundproof devices to decrease noise levels and to prevent noise disturbance should be acknowledged and obtain a certification (or "noise label") reporting noise performance, in order to permit both users and decision makers to compare and choose.

Regarding organizations and projects, noise footprint outcomes can be graphically represented as noise contours on a map. However, their purpose is not to duplicate and repeat the features of noise maps, but to give an original and significant contribution to environmental sustainability. In fact noise footprint aims at complementing noise mapping through a comparison with noise quality values, to identify areas more or less acoustically loaded. Obviously, this requires the application of common methodologies and models to provide comparable results. The gap between sound pressure levels and quality targets in an area affected by noise may be calculated in order to identify:

- the areas where additional facilities can be installed, in compliance with noise quality values;
- the areas where instead limits are exceeded and new activities can't start: this is a limitation to sustainable development, so specific actions and technologies to abate noise are needed.

We are not able to produce goods or services without consumption of resources and energy and without disturbing emissions. Noise can't be turned off: it is a limitation to sustainable development. Starting from the widely shared tools of noise mapping and acoustic zoning, it is necessary to switch to the innovative concept of noise footprint, referring to quality values and featuring a purpose of

environmental sustainability. Acoustic zoning sets the limits; the areas where noise levels are below the limits are potential districts for the sustainable development of the territory.

Limitations related to the proposed approaches at the organization, project and product levels include:

- the availability and selection of appropriate noise data and data sources;
- the assumptions regarding the different scenarios and the values needed to set the noise model.

Some data may also vary in time, so the outcomes and the accuracy of the quantifications of noise footprint may be influenced. When data are difficult to be estimated, approaches such as the assessment of noise emissions from in use sources may be preferable to integrate the methodology.

Dedicated software shall implement a common and complete database of noise sources, which must be certified and standardized. Collected sound emission data from all source types of interest shall be detailed, validated and shared worldwide.

A footprint analysis covers only a single impact category, but in principle its methodology may be applied to every environmental component. The proposed scheme of noise footprint may be conveniently extended, for example, to light and smell: the individual descriptors addressing the specific components of environmental sustainability (ecological, carbon, water as well as noise footprint) may contribute to the integrated assessment of sustainable development.

Finally, regarding how to measure noise footprint and how indicators have to be added into one aggregate descriptor, an agreement needs to be found.

Several difficulties and areas for improvement have been identifies, to be addressed in the ongoing experimentation and future developments.

REFERENCES

1. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 “relating to the assessment and management of environmental noise” and amending acts.
2. Brambilla G, Poggi A. Indicazioni operative per la costruzione dell’indicatore “Popolazione esposta al rumore” in riferimento alla Direttive 2002/49/CE. CTN-AGF; 18 January 2005; Bologna, Italy.
3. ISO 14020:2000 - Environmental labels and declarations - General principles - ISO, Geneva.
4. ISO 14024:1999 - Environmental labels and declarations - Type I environmental labelling - Principles and procedures - ISO, Geneva.
5. ISO 14025:2006 - Environmental labels and declarations - Type III environmental declarations - Principles and procedures - ISO, Geneva.
6. ISO 14064-1:2006 - Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of noise emissions and removals - ISO, Geneva.
7. ISO 14064-2:2006 - Greenhouse gases - Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements - ISO, Geneva.
8. ISO 14064-3:2006 - Greenhouse gases - Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions - ISO, Geneva.
9. ISO/TS 14067:2013 - Greenhouse gases - Carbon footprint of products - Requirements and guidelines for the quantification and communication - ISO, Geneva.
10 Cotana F, Nicolini A. Noise Mapping: the Evolution of Italian and European Legislation. Proc. Euronoise 2003; 19-21 May 2003; Naples, Italy 2003. paper ID: 198.
11. Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 “on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) ” and amending acts.
12. http://aratas.arpa.umbria.it/geoarpaumbria/gw/login.do?usr=guestrum&pwd=guestrum&amb=Umbria&pro=CatastoRumore_WEB
13. Asdrubali F, Simoncini C, Presciutti A. Il catasto acustico della Regione Umbria. Proc. Forum Acusticum 2005; 29-31 August 2005; Budapest, Hungary.
14. Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 “on machinery” and amending acts.
15. Piano di zonizzazione acustica del Comune di Perugia - Relazione tecnica. Università degli Studi di Perugia - Dipartimento di Ingegneria Industriale - Sezione di Fisica Tecnica, Comune di Perugia - Settore Ambiente e Territorio - U.O. Ambiente e Protezione Civile. January 2006; Perugia, Italy.