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A Comparison of Noise Mapping Methods in Italian and Russian Experiences

Sergio Luzzi
Ordine degli Ingegenri della Provincia di Firenze Via Stradivari n.23, 50127 Florence, Italy, sergio.luzzi@tin.it

Andrei V. Vassiliev
Togliatti State University, Belorusskaya Str. 14, Togliatti 445667, Russia, avassil@infopac.ru

Public Administration and Control Authorities, in compliance with the provisions of national and regional Laws, ask for careful and accurate studies of the acoustic climate of areas where industrial and residential sites coexist. The aim is to make more comfortable this coexistence and to estimate the compatibility of new settlements with the level of acoustic pollution of the mixed destination areas, with special consideration of transport noise as one of the main sources of annoyance. The paper refers to a comparison of experiences in noise mapping and action planning performed by the authors in Italy and in Russia according to the respective national laws and standards. Case studies concerning areas with point industrial sources and significant linear sources are described. Methods for noise mapping of urban sites interested by the proximity of heavy traffic urban road, regional and national motorways and railway lines are shown, as well as methodological approaches and models used to determine the acoustic climate of residential areas which formerly had industrial destination. With common reference to the ISO and other specific international standards, a compared analysis of different indexes and limits has been performed.

1 Introduction

For the time being acoustical pollution in modern cities is rapidly increased. More than 60% of population of large cities is living in exceeding noise conditions. Disturbing acoustical impact is appreciated by half of Earth population. Transport and industrial sources are making the most significant noise levels in the city environment. That is why it is necessary to estimate and monitor it. The paper refers to a comparison of experiences in noise mapping and action planning performed by the authors in Italy and in Russia according to the respective national laws and standards. Case studies concerning areas with point industrial sources and significant linear sources are described.

2 The Italian experience

2.1 EC Directive and Standards

The Directive 2002/49/EC of the European Parliament and of the Council of 25 of June 2002 refers to the assessment and management of environmental noise.

Annex II of Directive 2002/49/EC lays down four interim computation methods for the production of strategic noise maps based on the determination of Lden and Lnight indicators for road traffic noise, railway noise, aircraft noise and industrial noise are recommended. These methods are:

- the French national computation method 'NMPB-Routes-96 (CSTB) referred to as 'XPS 31-133' in the French standard, for ROAD TRAFFIC NOISE;
- the Netherlands national computation method published in "Reken en Meetvoorschrift", referred to as RMR, for RAILWAY NOISE;
- the ECAC Standard Method of Computing Noise Contours around Civil Airports', referred to as ECAC Doc.29, for AIRCRAFT NOISE
- the General Method of Calculation described in ISO 9613-2 "Acoustics abatement of sound propagation outdoors", referred to as ISO 9613, for INDUSTRIAL NOISE.

Member States that have already adopted strategic noise mapping and action planning methods are now involved in the general problem of joining the adopted methods with the main requirements of Directive 2002/49/EC.

Of course the use of interim methods and data provided in the relative guidelines is not compulsory, and Member States willing to use the interim computation methods are free to use other computation methods.

General problems are:

- the need to adapt methods and collected data expressed with noise indicators different from Lden and Lnight;
- the definition of standard emission data, that could cover all the specific situations that may be encountered in all Member States, in particular for road and railway noise; consequently, also specific methods for collecting data through measurements must be provided.

According to the Directive, there are important deadlines for urban noise mapping. Member States are required to:

- complete noise mapping before 30th June 2007
- complete action plans for management and reduction of noise before18th July 2008.

In order to assist the Member States in undertaking strategic noise mapping and produce associated data as required by the Environmental Noise Directive, the EC Assessment of Exposure to Noise (AEN) Working group has produced a "Good practice guide for noise mapping" [1] also taking into account international projects such as Harmonoise, Imagine [2] and others, involving noise source characterization and harmonized models.

2.2 Transport Noise in Italian Law

Italian law D.M. 29/11/2000 fixed the general approach for the definition of action plans concerning the reduction of transport noise. All the transportation companies and boards are invited to carry out acoustical studies of the respective contributions in noise pollution of the crossed areas. Systematic plans of monitoring and mapping noise levels leads to intervention plans scheduled in 15 years of progressive improvement, according to a priority scale.

Starting from a preliminary study and data acquisition of railway service conditions and territorial characteristics, the acoustic design process of mitigation actions of transport noise is composed of:

- traffic flows measurement and analysis for acoustical characterization of sources;
- acoustical mapping of areas containing noise receivers, located at fixed distances around roads, railroads and airports;
- assessment of noise produced by the road, rail or airport traffic;
- definition and design of interventions aiming at a reduction of noise levels below limits.

The evaluation of noise level is performed by:

- measuring (over a 24-hours or 7-days monitoring time) the source noise emissions in points at standard distances and heights all along the linear sources and all around the punctual ones;
- characterizing sources by type, speed, traffic volume and density, length or surface and other features;
- calculating the emitted sound power of each category of noise source (for example as logarithmic mean of the measured SEL level of all transits and events in that category);
- applying simulation algorithm to the measured data to find the noise impact levels ante-operam on each floor of each receiver facade.

The algorithms are not always referred to the interim computation methods and the noise indicators are Lday (from 6.00 a.m. to 10.00 p.m.) and Lnight, (from 10.00 p.m. to 6 a.m.). Lden is not considered at the moment.

Acoustic design contains the step by step definition scheme of localization, dimension and acoustical requirements of the barriers, with reference to the standard typologies adopted by the company or the public board. In the acoustic design the direct interventions on buildings are also described, with respect to the adoption criteria of the type of solution chosen by the company or board.

In Table 1 a standard design procedure for railway noise mapping and barrier design [3] is summarized.

Table 1: Railway noise mapping and barriers design in Italian experience

STEP 1: DATA COLLECTION AND ANALYSIS
- 3D Maps of railway patterns and ground profiles
- Railway buffers location and placement
- Location of interferences with electric lines and other installations, buildings, etc.
- Topographic and geological surveys
- Noise Receivers location and placement. Classification of receivers.
- Choice of measurement positions and measurement conditions
STEP 2: RECEIVERS MAPPING AND DATABASE
- Noise Receivers Database Creation
- Noise Receivers Map Plotting
STEP 3: MEASUREMENTS
- Measurements in points P_R (d=7.5 m, h=1.2 m) P_S (d= 25 m, h=4 m)
- Train and transit database
- Monitoring and calculation of railway noise indicators
STEP 4: ASSESSMENT
- Context implementation in a 3D layout system
- Emission levels calculation and source characterization
- Noise assessment and mapping ante operam with equal level curves in day-time and night-time
- Model validation
- Determination of acoustic parameters and geometry of barriers, determination of other mitigating actions
- Noise assessment and mapping post operam with equal level curves in day-time and night-time

STEP 5: DESIGN
- Final planning of barrier design and building, calculating the actual insertion loss.
- Draft of technical reports, plots and maps, according to standards

3 The Russian experience

3.1. Russian Sanitary Norms and Standards

In Russia noise levels in living area are evaluated according to hygiene requirements, stated by valid sanitary norms (Sanitary Norms 2.2.4/2.1.8.562-96 [4] Russian State Standards [5 etc.] and Building Norms and Rules. Normative parameters for unstable noise are equivalent sound levels L_{Aecv} and maximal sound levels L_{Amax}, dBA. There are two periods of evaluation: day (7.00-23.00) and night (23.00-7.00). If noise level is measured inside of building, the permitted value of L_{Aecv} is no more than 40 dBA (day) and 30 dBA (night), the permitted value of L_{Amax} is no more than 55 dBA (day) and 45 dBA (night). For the territories directly near to the living houses, hospitals, schools etc. evaluation of normative values of equivalent and maximal sound levels is carried out by using of following values (day):

$$L_{A\ ecv\ norm} = 55\ dBA + 10\ dBA = 65\ dBA \quad (1)$$

$$L_{A\ max\ norm} = 70\ dBA + 10\ dBA = 80\ dBA \quad (2)$$

For night period $L_{A\ ecv\ norm} = 55$ dBA, $L_{A\ max\ norm} = 70$ dBA.

3.2. Transport Noise Evaluation in Russia

In Russia the most serious problems of noise pollution in cities are caused by transport noise affection. When the scale of city transport flows is bigger, acoustic discomfort zones are considerable increased. Main input to transport noise generation in modern cities is provided by automobile transport (up to 90% from all population complaints). Automobile transport is intensive source of low-frequency noise generation, which is radiating from internal combustion engine intake and exhaust and by automobile tyres.

Evaluation of transport noise in Russia is carried out according to methodic recommended by Russian State Standard ГОСТ 23337-78* [6]. Results of measurements in every point must be presented as measurements registration forms including date, time and place of measurements, measuring points numbers and digital data of readings of noise levels in measured point (360 values for every point).

Noise of transport flows is unstable, oscillating in time. For this kind of noise there are some main requirements to carrying out the measurements:

- Time of noise evaluation T in houses of dwelling and public buildings and in living territory should be accepted in the day-time - continuously during 8 hours, at night - continuously during 0,5 hour (in the most noisy periods of day).

- Measurement of unstable noise should be carried out at the periods of time of noise evaluation T, which include all typical variations of noise regime in evaluated point. Duration of every measurement of unsteady noise T_m in every point should be at least 30 minutes.

- Reading of sound levels of interrupting noise, sound levels of which are remaining stable in the intervals with duration less than 0,5 minute, and also of oscillating and impulse noise should be carried out with intervals from 5 to 6 seconds. In every point during the period of noise T_m should be conducted 360 readings of sound levels etc.

Measured noise levels are distributed in intervals. Results of calculations are subdivided into columns and forms. Than individual indexes are determined according to the special table in depending on the interval and the number of readings of noise levels in this interval. Summary index is determined by addition of obtained individual indexes. Value ΔL_A, dBA, is determined depending on the magnitude of obtained summary index.

3.3. Modelling of Noise Propagation and the Methods of Noise Mapping

Modelling of noise propagation in the open space is more difficult task [7, 8]. Concerning transport noise evaluation it is better to model not noise of separate cars, but transport flow noise. Formalization and modeling of transport flows it is convenient to do by using of influence diagrams. Such diagrams are usually describing some formalized presentation of modeled categories (objects, processes, properties etc.) in a form of multitude of graphical symbols (assemblies, vertexes) and relations between it. In Russia the types of influence diagrams are the most popular to use in a form of flow graphs, trees of events and functional nets. Flow graphs are including the variety of vertexes and a set of regulated and of unregulated couples, using for visual presentation of modeling process. Trees – non orientated graph, not having cycles, finite and coherent. During last time semantic or functional nets are rapidly developing, which are present graphs, but with additional information in it assemblies and rib. The most popular functional nets PERT (program

evaluation and research technique) and GERT (graphical evaluation and review technique). For mathematical description of street-road nets of city methods of graph theory have been taken. Information about city street-road net geometry may be taken from the automobile road schemes, road atlases, drawings etc. For noise maps creation it is necessary to convert graph information to analytical. Presently the following steps have been done:

1. Mathematical apparatus of description have been analyzed and mathematical model of street-road transport nets have been worked out.

Variables and constants, meaning graph assembles-vertexes, are indicating as symbols set:

$U = \{1, 2, 3, ..., j, ... u\}$ - assembles-vertexes multitude;

$V = \{v1, v2, v_j, ... v_u\}$ - multitude of variables corresponding to assembles-vertexes;

$\Omega_j = \{\omega_1, \omega_2, \omega_3, ...\}$ – set of meanings of j-variable;

$f_j \in F$ – density of probability of distribution of variable y;

$\pi \in \pi$- function of accessory of linguistic variable.

For indication of relations between variables corresponding symbol mass data are using. These mass data may be presented as:

$D_{ij} = \{d_1, d_2, d_3, \ldots\}$ - multitude of ribs, connecting assembles i and j;

A_j - vector of bows-predecessers;

B_j - vector of bows-successers;

P_{ij} - vector of probability of transition between i and j.

Geometry of two-side graph G is determined by incidence matrix (setting a numbers of vertexes) and corresponding coordinates matrix $\{y^{(i)}\}$. To each rib $\{x^{(i1)}, x^{(i2)}\}$ of graph G numerical characteristic are comparing, which are describing street-road net:

n - number of traffic paths;
α - road profile;
β - quality of road surface;
γ - directives about structure and dynamic of transport flow;
δ - meteorological conditions;
ε - surrounding landscape;
θ – other characteristic (lighting, presence of traffic distribution zones etc.).

Thus, graph is totality of vertexes and ribs. Information about graph structure is determined by matrix form.

2. By using of developed mathematical model street-road transport nets have been created. Transport nets are consisting of the roads with intensive load (marked in the program by black bold strip) and a net of local roads. Numeration of graph assembles-vertexes is using. Procedure of graph cleaning from insignificant details is foreseeing.

3. Algorithms of coding and of information restoring about street-road graph structure have been developed.

4. Software have been developed to investigate noise situation in Togliatti city streets and roads. Graf networks of the transport mains of Avtozavodsky district of Togliatti city is shown in figure 1.

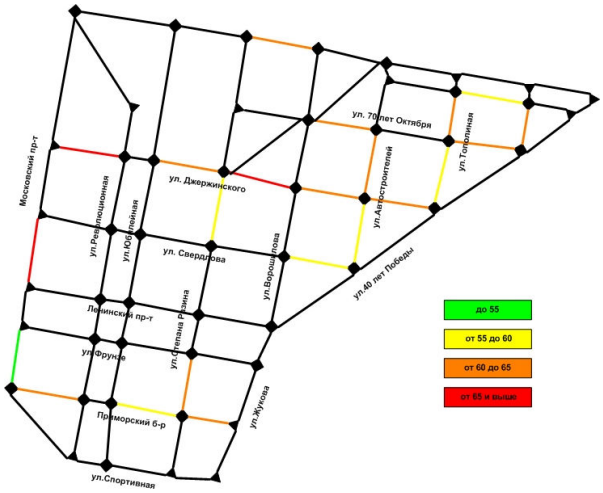

Figure 1. Graphical presentation of transport networks of Avtozavodsky district of Togliatti city

3.4. Examples of Noise Mapping in Russia

Rapid development of computing technique allows to automate the process of noise maps creation. Modern computers with high velocity proceeding huge volume of information as static, as graphical. As result, a lot of companies are suggesting different types of city noise mapping. Widely Geographic Information Systems (GIS) are used to provide accurate visual information about noise in city. It should be noted that existing noise mapping tool only showing the acoustical situation only in some defined period. Peculiarity of transport noise mapping is the fact that only transport noise is considered and such sources as industrial noise, internal noise of living areas are not taking to consideration. From the other hand, transport noise map is necessary to include all transport noise sources: automobile transport flows, aircraft noise, railway noise etc.

In Togliatti city there is only one main transport noise source: automobile transport. Collaborators of R&D Laboratory "Vibroacoustics, Ecology and Life Protection" have developed their own program provision for city noise maps drawing. Topographic method was used. Noise maps of Togliatti city have been developed. Noise map of the Central district is shown in figure 2. From the authors point of view it is very important that noise mapping software is to allow

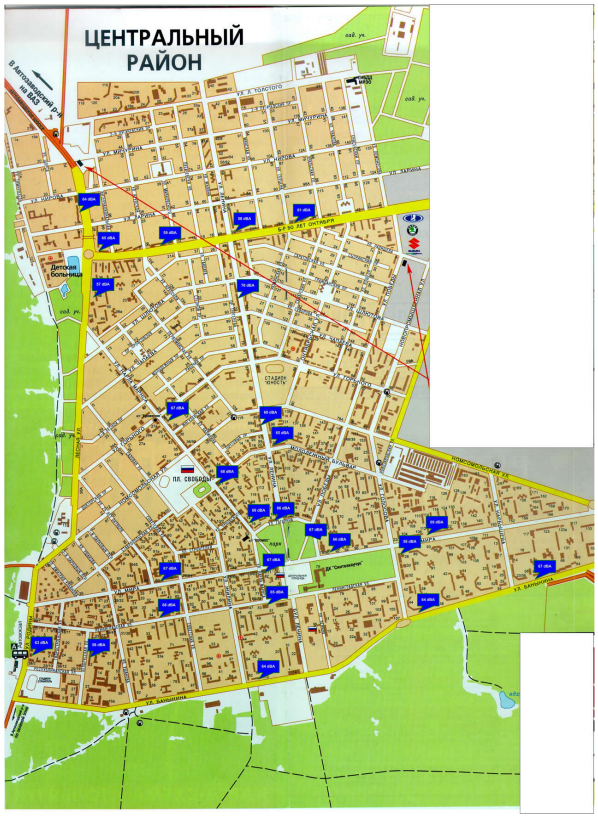

Figure 2. Noise map of Central district of Togliatti city

to carry out the storage of database on noise levels. This allows to carry out more efficient evaluation of transport noise in compare with traditional methods. Software "Sound City Test" (version 2) have been developed allowing to save in database the results of transport noise measurements for the all period of measurements. It is possible to add the data and to show on the map all the results of measurements and their dynamics. The window "Control Points" (figure 3) is logically subdivided into two parts: in the top – "Input and editing of points", in the bottom – " Input and editing of variations in points". All the points are presented in special form with network. The button «Add the point" allows to add new point to database (figure 4). The program is installed by loading the file IB6.exe from CD. Such kind of software allows to store all the measured data and to make a conclusion about the dynamics of noise time variations in nearest and far prospect. The method of presentation of results may be different: video-dB, graphs, tables etc. We named our software as "Dynamic noise mapping". Figure 5 is showing the loading of the map of selected part of living territory to the window. Figure 6 is showing the measuring results in the form of diagram.

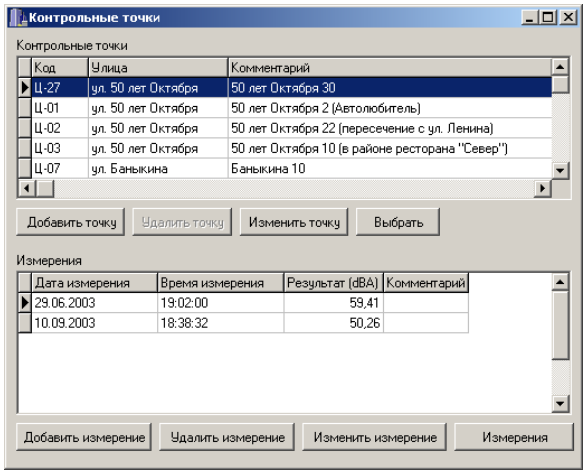

Figure 3. The window "Control Points"

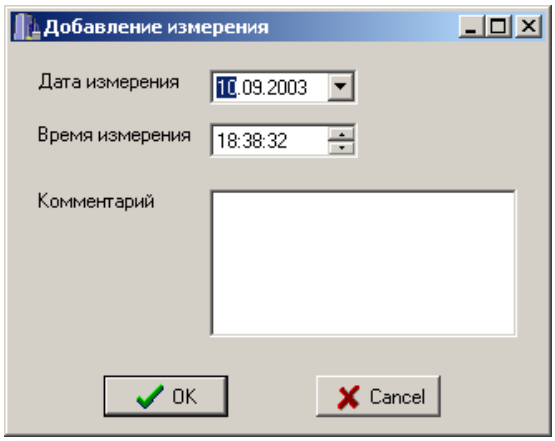

Figure 4. Opening the window during pressing the button «Add the point"

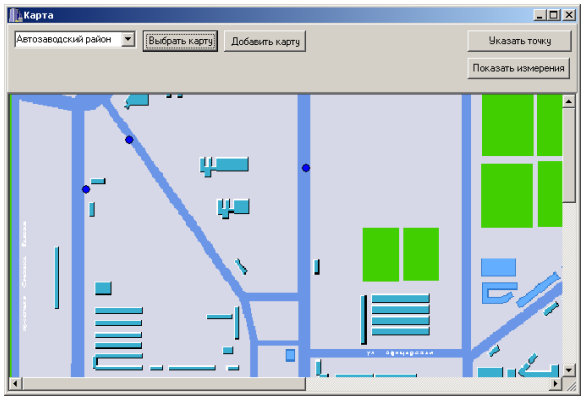

Figure 5. Loading of the map of selected part of living territory to the window

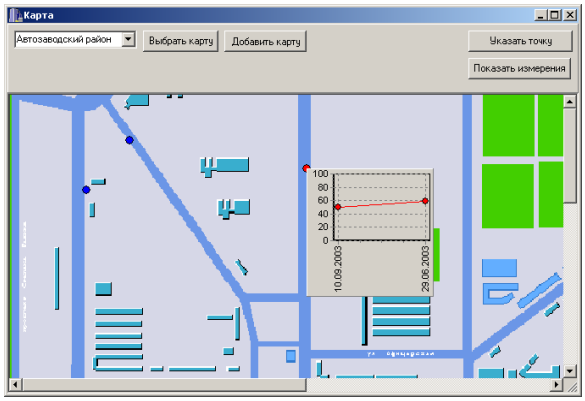

Figure 6. Display of measuring results in the form of diagram

4. Summary

Different methods of noise evaluation and mapping in Europe and Russia have been investigated and described. Analysis of mathematical modeling of noise propagation and evaluation in cities is presented. Different methods of noise mapping have been considered. The results of graphical presentation of transport networks and of topographical transport noise mapping have been presented. New method of noise mapping - "Dynamic noise mapping" - have been proposed. For further investigations it is necessary to develop the methodic of unification of European and Russian noise standards and mapping. It should include also the recommendations of joint impact assessment of different physical factors, like noise, vibration, infrasound etc.

The solution could be a joint project aiming to answer to the question of how to meet the methods of EU Directive on environmental noise, strategic noise mapping and action plans with the Russian standards and methods described above. The project could also consider the relationship between procedures and models that Russian laboratories are developing and applying with success and the new standards resulting from the Harmonoise and Imagine Projects. The purpose of these paper is to give evidence to the need of harmonized noise mapping methods as a contribution to the more general need of transposing, implementing and enforcing a common or harmonized environmental legislation between EU countries and other European countries in a possible pre-accession context or just in a collaboration context that could fix environmental noise descriptors and policy guidelines on which scientific and technical communities, governments, agencies, industry and citizens generally agree. The project could finally generate an international board, where acousticians and researchers, together with planners, architects, engineers, will meet their own experiences in design, specification, and construction of noise barriers and "built" environment, providing new international standards and compatibility rules.

Acknowledgement

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