Edinburgh, Scotland
EURONOISE 2009
October 26-28

Recent approaches to road traffic noise monitoring

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ABSTRACT

Noise pollution of living areas caused by road transport (mainly automobile transport) mapping presently is one of the most urgent problems. Transport noise in big cities is increasing every year.
In this paper the authors are presenting an experience of road traffic noise monitoring approaches and it realization in the cities of Russia and European Union.
One of peculiarities of Russian State Standards and Sanitary Norms devoted to the noise monitoring and estimation is the fact that noise is measured and evaluated only in day and night period. As an example of Russian experience the results of transport noise monitoring in the largest towns of Samara Region of Russia are considered.
In European Union countries the common way to evaluate traffic noise is based on weekly long period measurement, sometimes distinguishing and weighting working days from festive ones contributions. National models and interim models provided by END directive and by international projects follow rather heavy procedures, not yet completely harmonized.
Starting from the different approaches for road traffic noise monitoring and modeling presently used in Russia and in some EU countries, here described, authors give evidence to the differences, this allowing to suggest some new approaches that could lead to the creation of new integrated road traffic noise monitoring method also in consideration of the technological developments in the sound measurement and data transmission fields.

1. INTRODUCTION

Noise pollution of living areas caused by road transport (mainly automobile transport) mapping presently is one of the most urgent problems. Transport noise in big cities is increasing every year and makes the most significant input to the general acoustical pollution of modern towns. More than 60% of population of large cities is living in exceeding noise conditions, [1]. Damaging influence of intensive noise to the human's health is not restricted only by impact to ears. It is known, that noise is affecting to the human's central and vegetative nervous systems, influencing to the human's psychological condition etc. Transport noise level is increasing together with the cities growth. When the scale of city transport flows is bigger, acoustic discomfort zones are considerable increased. Noise level in large cities is growing every year approximately up to 0,5 dBA. Transport park in Russian and European cities is increasing every month. Therefore the problem of transport noise reduction in large cities is very important. Main input to

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transport noise generation in modern cities is provided by automobile transport traffic noise (up to 90% from all population complaints).
Efficient way of road traffic noise investigation and reduction is noise monitoring, including several branches: determination of noise dangerous zones on the basis of previous results, noise prediction tools development, real noise measurements, estimation of noise impact to the population health, noise mapping etc. Road traffic noise monitoring means using as good experimental measurement of transport noise levels as software development.
In this paper the authors are presenting some results of experience of road traffic noise monitoring approaches and it realization in the cities of Russia and European Union.

2. EXPERIENCE OF ROAD TRAFFIC NOISE MONITORING IN RUSSIAN FEDERATION

A. Some approaches to road traffic noise monitoring modeling and software development

In order to estimate, forecast and reduce transport noise it is necessary to develop efficient monitoring system. Software should include noise prediction tool; presentation of the results of measurements and investigations; calculation of the efficiency of noise reduction, noise mapping etc. The area of software using is continually increased. Here we are underlying some kinds of software for transport noise monitoring [1]:
1. Software for processing and evaluation of experimental noise data.
2. Software for evaluation of noise propagation in cities living areas.
3. Software for transport noise investigation in city roads.
4. Software for transport noise mapping in some areas of city territory.
5. Software for determination of transport noise among of the other noise sources etc.

We may see that transport noise monitoring need completely different program products. It is rather difficult task to create a good quality software for evaluation of noise propagation in cities living areas because sound propagation in living areas is sophisticated process, characterized by such phenomena as sound waves divergence, interference, diffraction, refraction, reflection, absorption etc.

In modern multi-stored building of living territories near to highways with long houses and front houses arrangement along the streets reduction of sound level is determined mainly by divergence and by screening effect. In little-stored building effect of screening is slight, role of sound reflection is increased, significant role is gaining surface type of the territory, and main input is given by the straight sound energy, or sound energy, diffracted on buildings butt-ends. Some influence to noise propagation may give greenery: trees, shrubs. Significant influence on noise propagation inside of living territories exercise the screens: solid walls, land embankments, slopes of hollows etc. Noise propagation inside of the living houses is occurs through the protective constructions, total sound isolation of which is determined by the most weak elements, and first of all by windows and by balcony doors.

Mathematical model have been developed to evaluate transport flows noise propagation to the dwelling territory. Transport flow is presented as a model, consisting of indefinite number of incoherent noise source of equal sound power, situated on one straight line on the equal distance each from other. In general such noise source is considered as complex source of pseudo-cylindrical sound waves (sound pressure level of which is reduced for every doubling of distance in limits from > 3 up < 6 dB depending on the distance between noise sources).

Differential equation of such waves propagation is following:

$$\frac{\partial^2}{\partial}\frac{p}{t^2} = c^2\left[\frac{1}{r^n}\{\frac{\partial}{\partial r}r^n\frac{\partial p}{\partial r}\}\right]; \quad (3)$$

where $1 < n < 2$.

If n = 1, we have equation of propagation of cylindrical waves, if n = 2 - equation of propagation of spherical waves.

Section of pseudo-cylindrical surface is determined as:

$$S - 2\pi r^n; \quad (4)$$

Transport flow (independently on it density) may be also considered as linear noise source, what is significantly simplifies calculations. But it should be bear in mind, that this admission is valid only for the cases when noise characteristic of flow is equivalent sound level for the period of time, exceeding duration of vehicle passing. Square of sound pressure at the distance r from linear noise source is expressed as:

$$p^2 = \frac{W\rho c}{2\pi r}; \quad (5)$$

Sound pressure level (dB) with its location on the acoustically rigid surface L_p, is determined by the equation:

$$L_p = L_W - 10\lg 2\pi r. \quad (6)$$

B. Methodic and some results of road traffic noise measurements in Russia

Noise levels in living areas (including transport noise) in Russia are evaluated according to hygiene requirements stated by valid sanitary norms (Sanitary Norms 2.2.4/2.1.8.562-96), Russian State Standards [2 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; (7)

$L_{A\ max\ norm}$ = 70 dBA + 10 dBA = 80 dBA; (8)

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

One of peculiarities of Russian State Standards and Sanitary Norms devoted to the noise monitoring and estimation is the fact that noise is measured and evaluated only in day and night period. As an example of Russian experience the results of transport noise monitoring in the largest towns of Samara Region of Russia are considered.

Togliatti city has as a number of large industrial enterprises as considerable automobile transport park, making significant acoustic impact to abutting dwelling territory. The problem is intensified by the fact, that some industrial enterprises and highways are closely adjoining to city's dwelling area. As result significant part of city's population is affected by increased noise level. Automobile transport is the main external noise source affecting to Togliatti city dwelling area. Specific city peculiarity is large automobile transport park, the most part of which consist of cars. This causes intensive transport flows at city's streets, which are generating significant noise impact. Noise of moving automobile is forming by the noise from the engine and its systems, automobile aggregates, oscillating body, tires, noise of auxiliary equipment etc. Taking to account continuous growth of city's automobile park, presently the problem of transport noise impact is coming urgent. It should be noted that for Togliatti city comparatively homogeneous composition of transport flows is typical - rail city transport is absent, impact of aircraft noise is excluded.

In years of 2001-2009 collaborators of R&D laboratory "Vibroacoustics, Ecology and Life protection" of Togliatti State University have carried out investigation of external noise sources affection to living area of Togliatti city [1]. The most significant excess of standard equivalent noise levels have been observed in the Central and Komsomolsky districts of Togliatti city: in Mira street, Banykina street, Komsomolskaya street, Lenina Str. (Central district), Matrosova Str., Yaroslavskaya Str., Chaykina Str. (Komsomolsky district). Results of comparison of measured and calculated values for every point with normative requirements shows, that the value of exceeding of normative requirements of equivalent noise level have achieved 13 dBA, maximal noise level - 12 dBA. In Avtozavodsky district living area the following zones with the exceeding of normative requirements of equivalent noise level were found: night time: point A-32, Dzerzhisky Street, the value of exceeding of normative requirements of equivalent noise level is 8 dBA, maximal noise level - 3 dBA; day time: point A-04, Topolinaya Street, 21, the value of exceeding of normative requirements of maximal noise level - 19 dBA; point A-12, Dzerzhisky Street, 31, the value of exceeding of normative requirements of equivalent noise level is 3 dBA.

In total from more than 200 points of measurements only 60 meets to the normative requirements of equivalent noise level and 56 - to maximal noise level.

Analysis of recent measurement results of external noise levels in living territory of Togliatti city shows, that noise level is increased approximately in 0,5 - 1 dBA per year. Especially urgent problem of noise reduction in night time: measurements data shows, that for all measuring points the normative requirements were exceeded. Values in a number of measured points in day time are exceeding the norms or extremely close to maximally admitted normative requirements.

The similar situation was observed in other large town of Samara region: Samara, Syzran, Zhigulyovsk.

C Experience of road traffic noise mapping

There are the different methods of noise mapping. One of the methods is using of topographic data, schemes etc. of living territory. Measured and calculated results in very of points of measurements are drawing to the map, noise dangerous zones are marked. There is possibility of noise situation forecasting in the living territories which are similar to the investigated territory. The scale of map may be completely different and depending on the required task: city map, districts maps, neighbourhood units maps and even living houses maps.

From the other methods of noise maps creation first of all, transport noise method should be pointed out. Only transport noise is taken into consideration, and not any other sources. In this case noise map is good situational material of city with definite street-road

net, in which equivalent noise levels are marked in typical points. Method of indication of equivalent noise levels may be also different. The most clear method is varying of colour intensity: from light for low noise levels to dark – for high noise levels

Rapid development of computing technique allows to automate the process of noise maps creation [1, 4, 5 etc.]. 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 maps. For example, well known «LIMA» and «SoundPLAN» program provision. 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.

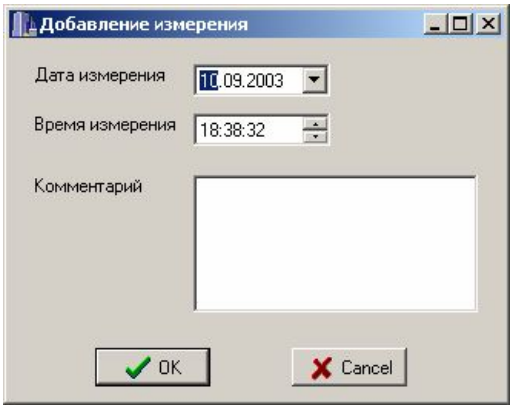

Figure 1: Opening the window during pressing the button «Add the point"

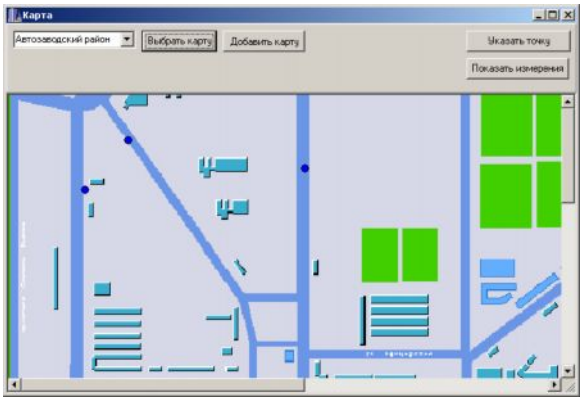

Figure 2: Loading of the map of selected part of living territory to the window

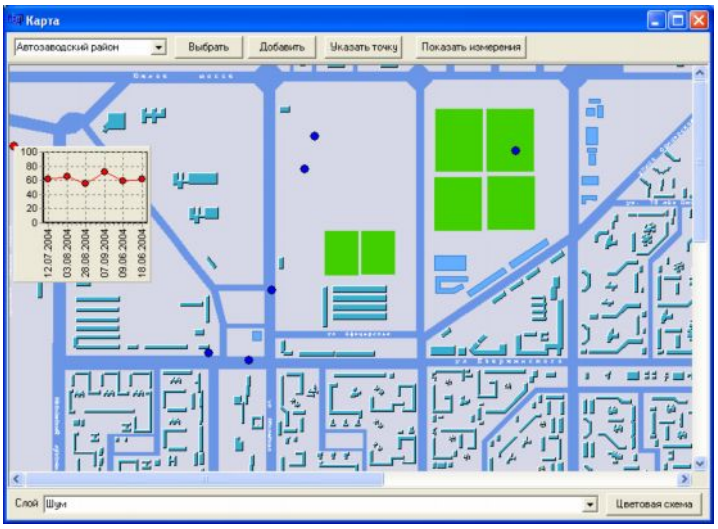

Figure 3: Display of measuring results in the form of diagram

In Togliatti city there is 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. Program complex «Sound City Test» have

been developed for sound and other physical pollutions mapping design. Software allows 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" 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 1). The program is installed by loading the file 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 2 shows the loading of the map of selected part of living territory to the window. Figure 3 shows the measuring results in the form of diagram.

For editing of color scheme it is necessary to select in the main menu point "Service", sub-point "Color Schemes". Then we may see the window "Color Scheme" (figure 4).

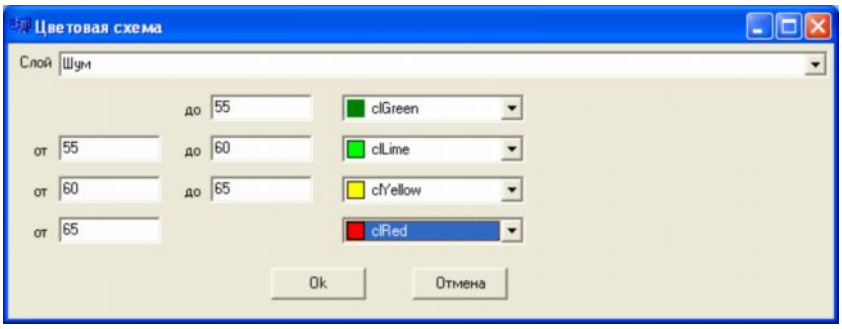

Figure 4: Window "Color Scheme"

3. EXPERIENCE OF ROAD TRAFFIC NOISE MONITORING IN EU

In European Union countries the common way to evaluate traffic noise is based on weekly long period measurement, sometimes distinguishing and weighting working days from festive ones contributions. National models and interim models provided by END directive and by international projects follow rather heavy procedures, not yet completely harmonized [3, 4].

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. 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.

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.

4. NEW APPROACHES TO ROAD TRAFFIC NOISE MONITORING

Starting from the different approaches for road traffic noise monitoring and modeling presently used in Russia and in some EU countries, here described, authors give evidence to the differences, this allowing to suggest some new approaches that could lead to the creation of new integrated road traffic noise monitoring method also in consideration of the technological developments in the sound measurement and data transmission fields.

Figure 4: Structural scheme of «Physic City Test» software

One of the new ideas id to estimate noise in integration in other physical pollutions. For this purpose software «Physic City Test» have been developed consisting of the following main modules:

1. Module of input and automating processing of results of measurements of different physical pollutions. Allows to carry out input of primary data (measurements results) and it preliminary processing.
2. Module of estimation of measurements results to satisfy to the sanitary norms requirements. Allows to determine the points with increased noise levels.
3. Module of integrated estimation of different physical pollutions. Allows to account the summary impact of different physical pollutions.
4. Module of mapping of physical pollutions. Allows to see all the points and results of measurements and to design the maps of physical pollutions.
5. Educational module: used for the purposes of the students and postgraduates teaching on the subjects of acoustics and environmental protection.

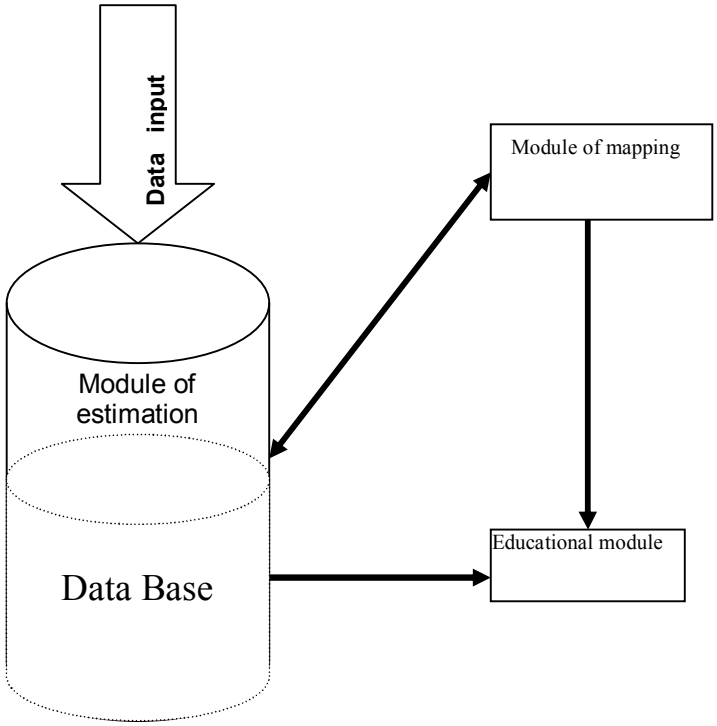

Figure 5: Interaction of different modules

Structural scheme of «Physic City Test» software is shown on the figure 4. Interaction of different modules is shown on the figure 5. The sequence of input data and procedure of calculations is shown on the figure 6.

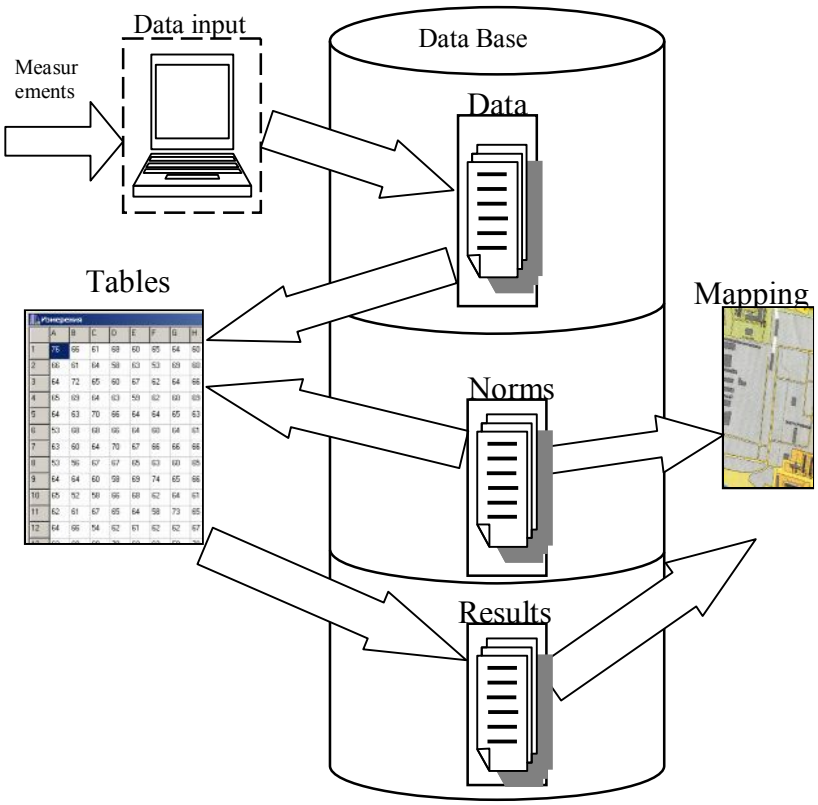

Figure 6: The sequence of input data and procedure of calculations

5. CONCLUSIONS

An experience of road traffic noise monitoring approaches and it realization in the cities of Russia and European Union have been presented. Different methods of transport noise monitoring have been described. Analysis of mathematical modeling of noise propagation and evaluation in cities have been provided. Starting from the different approaches for road traffic noise monitoring and modeling presently used in Russia and in some EU countries, here described, authors give evidence to the differences, this allowing to suggest some new approaches that could lead to the creation of new integrated road traffic noise monitoring method also in consideration of the technological developments in the sound measurement and data transmission fields. The concept and software structure of the new integrated road traffic noise monitoring method have been described.

ACKNOWLEDGMENTS

The first author would like to express many thanks to the to the Russian Ministry of Education and Science for the financial support of investigations according to the grant of the leading Scientific Schools of Russia (Sc. school 4545.2008.8)

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