Calculating and 3D-Modeling of Traffic Noise in Magadan, Russian Federation, with the Use of the Software Package Acoustic 3D Automated Workstation

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Abstract

The object of this study is practical testing of Automated Workstation software package in real urban conditions in order to identify the shortcomings of domestic noise calculation methods implemented in the software package. The results of traffic noise modeling using the Acoustic 3D automated workstation program are presented; field surveys of urban areas have been carried out, calculations have been made in the software package and traffic noise maps have been built. The disadvantages of the noise calculation methodology implemented in the automated workstation program have been distinguished – typical coefficients, the use of which leads to an increase in the error of transport noise calculations, have been determined. The author has predicted indicators of traffic noise for various classes of highways using his own mathematical model. The application of the one-factor model is proposed as a practical solution to the issues and in the future – the development of a multifactor model for assessing traffic noise.

Keywords: road traffic noise; assessment and forecasting; noise calculation techniques; improvement of methods.

Introduction

Nowadays mathematical modeling has become an integral part of traffic noise research. This is because of the fact that noise has a significant impact on human health (Babisch, 1985), therefore it is important to identify areas unfavorable for living and solve the problem of noise timely. A lot of researches carried out in Russia and abroad bring science closer to the moment when the use of noise meters becomes unnecessary (Kirushina, 1994; Iannelli, Pronello 2000; Conti, 2000; Sun et al., 1994). Models, where field or calculated data on the maximum hourly traffic intensity are used as initial data, are widespread.

However, at the present time in the road regulatory documentation, the planning of traffic noise indicators is provided at an insufficiently qualitative level. Industry-specific techniques, such as Road Industrial Methodical document (ODM) 218.2.013-2011, are intended to predict traffic noise at designed facilities. Accordingly, their effective application for the tasks of assessing traffic noise on existing highways is questioned, since calculated data on Road Industrial Methodical document are objectively too high compared to field indicators (Vasilev et al., 2020). In Set of Rules (SP) 276.1325800.2017 Section 6 contains a table with predicted indicators of the noise characteristics of traffic flows (hereinafter – NCTF), depending on the category of

highways (Set of Rules (SP) 276.1325800.2016. Buildings and territories. Rules for designing protection against traffic noise, 2017). The indicators are 10 to 20 % higher than the real values obtained by the author using the Octava-110A sound level meter.

Based on additional experimental studies, the discrepancy between typical indicators proposed in industry documents and real data was confirmed (Vasilev et al., 2020; Ivanov et al., 2017; Krikun, 2019). Thus, in our opinion, it is not possible to assess the real level of traffic noise on operated city roads and to predict measures to reduce the noise effect from vehicles without a sound level meter.

At the same time, the practical application of modern software systems based on domestic regulatory documentation will allow a deeper analysis of the options for improving the accuracy of the calculation methods for traffic noise. In combination with the above, modeling and construction of noise maps will make it possible to assess the actual state of noise pollution in the urban area according to the author's own methodology and standard methods implemented in the software package Acoustic 3D automated workstation (Ivanov et al., 2017). From a commercial research perspective, noise mapping can be an important factor in ensuring competition with other urban noise pollution organizations.

The research objective is the application of Acoustic 3D automated workstation software on real territories of Magadan and the development of directions for improving methods for assessing traffic noise.

Research problems:

1. Areas for modeling traffic noise were identified; geometrical parameters of buildings and territories were surveyed.
2. Calculations were made and noise maps were constructed for the studied territories.
3. The methodology for predicting traffic noise, implemented in the software package Acoustic 3D automated workstation, was analyzed.
4. The directions for increasing the accuracy of methods for assessing traffic noise without the use of sound level meters are presented.

Methods

Noise maps of urban areas have become a common tool for identifying foci with high noise pollution. In numerous dissertation studies, noise mapping is one of the main tasks. This is due to the fact that modern software systems for building maps perform not only and not much of visualizing the levels of noise pollution, but first of all, they allow modeling and predicting changes in noise in territories and rooms under the influence of various factors. For example, according to the dissertation of Butorina, one example of a new approach to the design of highways is monitoring and forecasting the noise environment using electronic computerized noise maps, which are an effective tool to combat noise, providing the user with objective information about the noise regime of the territory and providing the basis for developing the most rational noise protection measures. Thus, the advisability and necessity of using noise maps in environmental studies are beyond dispute.

Software Acoustic 3D automated workstation is designed to solve the following tasks:

- creation of a spatial scheme for the location of calculation objects on the territory using the GIS interface;
- input and storage of information on spatial and technological characteristics of noise sources, obstacles, calculation points;

- calculation of acoustic impact from point, linear and area noise sources on the territory;
- calculation of external noise penetrating the room;
- calculation of the required reduction in sound power levels for noise sources;
- the output of a detailed report with the progress and results of calculation of acoustic impact for the selected calculation point in Microsoft Excel;
- construction of noise maps depicting noise sources impact on the adjacent territory in the form of color maps and isolines of equivalent sound level and sound pressure levels in octave bands 31.5...8000 Hz;
- construction of three-dimensional noise maps of noise sources impact on the adjacent territory in the form of color maps and isolines of equivalent sound level and sound pressure levels in octave bands 31.5...8000 Hz;
- construction of vertical noise sections along an arbitrary section in the form of color maps and isolines of the equivalent sound level and sound pressure levels in octave bands 31.5...8000 Hz;
- maintaining a database of noise characteristics of technological equipment.
- The study presents data on some sections of Magadan city roads, in the territory of which field measurements of noise and traffic flow were carried out.

Despite the high relevance of the study of some sections in the city center with buildings located in close proximity to roads, bypass highways are of some interest. They are interesting first of all because bypass highways have a different from other roads traffic composition, type, and condition of the road surface with comparable maximum hourly traffic intensity (Pospelov et al., 2017). It was important to consider this during the field measurement phase. However, the construction of noise maps requires the selection of road sections where traffic noise poses a direct threat to public health. Basically, these are highways located in densely populated areas of the city, where violations of sets of rules in terms of ensuring the normative distance between residential buildings and city highways are traced.

The main criteria for the selection of urban road sections are the following: high traffic intensity, location of buildings in close proximity to city roads, and different positions of buildings in relation to the road on the studied objects. According to these criteria the following sections of city roads were chosen for building noise maps: Karla-Marxa, 49-51; Proletarskaya, 38-40 and Proletarskaya, 79.

Results

The results of an automated calculation of traffic noise for the site on Proletarskaya, 79 are presented in Table 1.

Table 1. Results of traffic noise calculations in software Acoustic 3D automated workstation

The final results of determining the sound pressure levels at the point Proletarskaya, 79 (point coordinates, m: x = 119340.84, y = 92781.86, z = 1.50)												
Noise source	Characteristic	Sound pressure levels, dB, in octave bands, with geometric average frequencies, Hz									La, dBA	Lmax. dBA
		31.5	63	125	250	500	1000	2000	4000	8000		
1	2	3	4	5	6	7	8	9	10	11	12	13
	Levels of sound pressure from the source at the design point during the day	0	75.1	67	62.3	60	61.2	57.6	52.5	43.6	65.1	73.2
	Levels of sound pressure from the source at the design point during the night	0	67.7	59.6	55	52.7	53.9	50.3	45.1	36.3	57.8	73.2
	Required reduction during the day, ΔLreq, dB	0	5.1	6	8.3	11	16.2	15.6	12.5	4.6		
	Required reduction during the night, ΔLreq, dB	0	5.7	7.6	11	13.7	18.9	18.3	15.1	8.3		
	Total sound pressure levels at the design point from all noise sources during the day, Ldp, dB	0	75.4	67.1	62.4	60.1	61.3	57.7	52.5	43.6	65.2	73.2
	Total sound pressure levels at the design point from all noise sources during the night, Ldp, dB	0	68.1	59.8	55.1	52.8	54	50.4	45.2	36.3	57.9	73.2
Permissible SPL during the day, Lper, dB	territory near a residential building Table 3[2]	85	70	61	54	49	45	42	40	39	50	70
Permissible SPL during the night, Lper, dB	territory near a residential building Table 3[2] 78		62	52	44	39	35	32	30	28	40	60
	taking into account the correction -5 dB for the operation of technological equipment											
	Excess during the day, dB	-85	5.4	6.1	8.4	11.1	16.3	15.7	12.5	4.6	15.2	3.2
	Excess during the night, dB	-78	6.1	7.8	11.1	13.8	19	18.4	15.2	8.3	17.9	13.2

Daily traffic intensity was determined according to Road Industrial Methodical document (ODM) 218.2.013:

$$N_{\text{daily}} = 16N_{\text{max}}^h \quad (2.1)$$

where N_{max}^h is maximum hourly traffic intensity during the day, obtained using field observations, auto/hour.

Instead of a standard rate of 16, a field-based research value was used, which ranges from 10 to 12. The maximum hourly traffic intensity was also taken according to measurements for a specific site. Thus, the daily traffic intensity for the studied sections was: Karla-Marxa – 11000 auto/daily, Proletarskaya (38-40; 79) – 15000 auto/daily. Coefficients were introduced that take into account the parameters of traffic flows (speed and composition of traffic) and geometric parameters of the carriageway (width of the carriageway and dividing strip).

The results of modeling of traffic noise with the use of the software package Acoustic 3D automated workstation confirmed the excess of standard noise levels in the area adjacent to residential buildings. On the section on the street Proletarskaya, 38-40 – 21-24 dBA, on the section on the street Karla-Marxa, 49 – 18-21 dBA, on the street Proletarskaya, 79 – 15-18 dBA. The exact use of correction factors, taking into account the development and parameters of urban roads, allows us to obtain the values of equivalent sound levels exceeding the full-scale values by about 10 dBA. This error is lower than the error obtained by direct use of the Road Industrial Methodical document (ODM) 218.2.013 methods, which indicates a fairly high-quality databank with external conditions in areas taken into account in the mathematical apparatus Acoustic 3D automated workstation.

Below are the noise maps modeled in the software package Acoustic 3D automated workstation (Figures 1-3).

- 1 – urban transport highway (noise source); 2 – landscaping line along the road (grass, shrub, trees);
3 – noise map (area of study); 4 – group of residential buildings; 5 – indication of noise levels

Figure 1. Map of traffic noise on the site on the street Karla-Marxa, 49-51

1 – urban transport highway (noise source); 2 – noise map (area of study); 3 – green area in the local area (grass, shrubs, trees); 4 – group of residential buildings; 5 – indication of noise levels

Figure 2. Map of traffic noise on the site on the street Proletarskaya, 38-40

1 – urban transport highway (noise source); 2 – hollow space (area below road level); 3 – noise map (area of study); 4 – group of residential buildings; 5 – indication of noise levels

Figure 3. Map of traffic noise on the site on the street Proletarskaya, 79

Discussion

In this article, we present the results of traffic noise modeling with the use of the Acoustic 3D automated workstation tools. Based on the results of calculations performed in the program, it can be concluded that the prediction of traffic noise is carried out with the same error that is obtained by direct use of mathematical formulas from industry methods. Thus, the problem of local assessment of traffic noise in the conditions of the existing urban infrastructure in the tested program is not fulfilled. The development of such a methodology and corresponding software tools may be relevant in the near future.

Some researchers come to the conclusion that the existing deviation of the predicted data from the full-scale data obtained on the sound level meter is explained by the obsolescence of regulatory documents (Vasilev, Ksenofontova, 2020). However, the analysis of the parameters carried out by the author showed that there are other reasons for this problem:

1. The predictive purpose of the methods is to ensure the reliability of design solutions up to 20% in the design of highways.
2. Variability of transport and operational parameters. As a result of the urban transport systems development, the composition of traffic, the structure, and external noise of cars and trucks change, the characteristics of road surfaces are improved.
3. Underestimation of factors that take into account the regional specifics of transport systems.
4. A significant difference in the requirements for carrying out field studies of traffic noise in foreign and domestic methods. In this situation, it becomes difficult to analyze and compare the data obtained by individual researchers, and, therefore, it is difficult to take into account the experience of foreign scientists when constructing mathematical models.

The first step towards solving the problem stated by the author was the accumulation and processing of statistical data obtained experimentally. This allowed us to obtain a one-factor dependence, where the input parameter is the maximum hourly traffic intensity. In the practice of calculating noise levels based on the maximum hourly traffic intensity, the approach is not new, since it is implemented in industry road documents. However, obtaining such a dependence based on field data has a certain novelty. The deviation of the calculated and field indicators in this case is not greater than 6% (Krikun, 2019).

Traffic noise indicators for sections of main streets were modeled on the basis of the maximum hourly traffic intensity using the stochastic model developed by the author. The obtained calculated indicators are approximated in accordance with the current classification, data obtained on the sound level meter. The indicators are listed in Table 2.

Table 2. System of criteria and measures to reduce traffic noise on main streets and roads (Set of Rules (SP) 396.1325800.2018 Streets and roads of settlements. Urban planning rules, 2018)

Motorway category (Set of Rules/SP 396.1325800.2018)		Predicted maximum hourly traffic, auto/h	Predicted equivalent sound level of traffic noise, dBA	Measures to reduce traffic noise	
				Type of activity	Effect, minus dBA (equiv.)
2 nd class	Main streets of city-wide significance	1500 to 2000	65-67	A1, A2, B1	3 to 7 dBA
3 rd class		1000 to 1500	63-65	A1, A2, B1, C	
-	Main streets of district-wide significance	500 to 1000	60-63	A1, A2, C	Up to 3 dBA
-	Streets and roads of local significance	Up to 500	Less than 60	A2, C	

The proposed criteria are developed on the basis of field data and modeling results, therefore, reliable.

A system of measures to reduce noise has been developed with the designation of their types:

1. “A” – measures to regulate the intensity of traffic flows, where:

2. A1 is for measures of transit transport organization (creation of intercepting parking lots at the entrance to the city, expansion of the routes of the ground public transport network with attachments to parking places, creation of pedestrian infrastructure to the nearest public transport stops).
3. A2 is for measures of intracity transport organization (reduction of free parking lots along sidewalks on city streets, increase in the number of ground public transport units, creation of ring-shaped routes around the main urban area with classic buses or metrobus type).
4. “B” – measures to improve road infrastructure and traffic management, where:
 - B1 is for improving and maintaining the noise characteristics of road surfaces (reducing the roughness of road surfaces on sections of urban roads with high-density development, increasing the wear-resistant properties of road surfaces, reducing premature wear of road surfaces in winter).
 - B2 is for improving the organization of traffic (restricting the movement of passenger and freight vehicles on the far right lanes of the carriageway in high-density development conditions, introducing a paid entry for passenger vehicles into areas with a high concentration of the urban population, adapting the road network to bicycle and motor transport of class L1).
5. “C” - reduction of external noise from vehicles (toughening the requirements for technical control of vehicles with the introduction of external noise control, replacing the fleet with cars with hybrid or electric power plants).

Conclusion

The following conclusions are made based on the results of the study:

In the description of the programs “Ecologist-noise” and AWS “Acoustics”, it can be noted that as part of the programs functionality the developers present an assessment of noise levels in the conditions of the existing infrastructure of cities, similar to the assessment carried out on measuring equipment. However, none of the presented complexes allows you to calculate the equivalent and maximum sound levels as accurately as the data obtained on a sound level meter. The problem lies in the regulatory documents that underlie the software systems and in the approved techniques.

In our opinion, a clear separation of the concepts of “noise prediction” and “local noise assessment” is required nowadays, since the first task is 100% completed, and the second task is not completed but is artificially replaced by the first one. Thus, the direction in which the improvement of noise modeling programs will completely replace the sound level meter seems promising. This will require the development of a multifactorial mathematical model that allows taking into account all infrastructure, transport, operational and climatic factors.

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