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JOURNAL OF ENVIRONMENTAL ENGINEERING AND LANDSCAPE MANAGEMENT
ISSN 1648–6897 print/ISSN 1822-4199 online
2011 Volume 19(1): 62–70
doi:10.3846/16486897.2011.557249

MODELING OF THE SPREAD OF MOTOR TRANSPORT NOISE IN ŠIAULIAI CITY

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Submitted 22 Apr. 2009; accepted 16 Oct. 2009

Abstract. Rapidly growing urbanization causes the increase of noise level of various sources, that have a negative impact upon people's health. The contribution of noise caused by motor transport in city environment composes up to 80% of general impact of all the sources.

The article presents the results of modeling of the spread of motor transport noise of Šiauliai city, maps of motor transport noise, recommendations for management of environment noise.

MapNoise programme module, adapted to work in the ArcGIS Desktop 9.1 environment, was used for modeling motor transport noise. Noise measurement researches have been carried out using digital noise isolator Nor121, completed with digital level detector. NorXfar software was used to send the data to personal computer. Having evaluated the validity of modeling results it has been determined that the difference between the night noise modeling and measurement results does not exceed 2.2%, and varies from 0.5 dB(A) to 1.1 dB(A). The obtained results indicate that 7.2% of the apartments of all city residents are influenced by the L_{DEN} noise that exceeds the permitted noise level (L_{DEN} > 65 dB(A)) and 31.2% of the apartments of the residents are influenced by night noise that exceeds the permitted noise level (L_N > 55 dB(A)).

Keywords: investigations of noise, transport noise, noise indexes, map of motor transport noise, modeling of noise.

1. Introduction

Development of urbanized territories, industrial districts, roads, railroads, infrastructure of air transport more and more expands the zones of acoustic discomfort that involve more residential and public territories and residents present in these territories. The greatest sources of anthropogenic origin noise are the noise of transport (roads, railroads, air), industrial objects, public noise (Ustinavičienė *et al.* 2004; Baltrėnas *et al.* 2004).

The impact of noise upon the organism first of all is related to the intensity of irritating impact caused by noise. The impact of noise upon human's organism depends on the manner of noise (intensity, spectrum of frequencies, etc.), time and duration of impact, as well as individual organism features: age, health, noise sensitivity. Elderly people, people having physical and mental disability, working in noisy environment are the most sensitive to noise. First of all, irritating noise effect depends upon individual evaluation of noise as unwanted i.e. irritating and disturbing. It depends upon individual reactions, psychological response and person's ability to overcome tension. Noise is subjectively evaluated as stressor and this subjectively perceived irritant has impact upon health. Model of noise, as a source of stress: sound (subjectively perceived sound) – stress indicators (increased production of stress hormones) psychophysiological risk factors (arterial blood pressure, blood lipids, glucose, etc.) – heart and veins' diseases (Rimovskis, Ramonas 2005; Mačiūnas *et al.* 2007).

Health hazard appears when sound level for adults is higher than 140 dB(A), for children 120 dB(A); therefore, a person may become deaf right away. 110 dB(A) noise level may cause temporary deafness. If sound level is always higher than 85 dB(A), hearing lesion may be caused, hearing might weaken (Oškinis *et al.* 2004).

According to the data of World Health Organisation (WHO), even 40% of residents of European Union are affected by increased environment noise during the day and around 20% – during the night. In Europe every day 450 million people are affected by 55 dB(A) noise level, 113 million – 65 dB(A) and 9.7 million experience 75 dB(A) noise (Transportinio triukšmo… 2005).

Motor transport noise composes 80–82% of general noise level in city territories. Various urban, technological, administration and constructional means are applied to reduce noise impact. Using windows with various glass package constructions, the noise coming from the street in a room may be reduced from 15 to 32 dB(A). Noise screens may reduce noise level behind the screen from 9 to 12 dB(A) (Rimovskis, Ramonas 2005; Transportinio triukšmo… 2005; Baltrėnas *et al.* 2007; Crocke 1999).

Noise management in European Union is regulated by Directive 2002/49/EC adopted in June 25, 2002 "Regarding the Evaluation and Management of Environment Noise". Its goal – to describe general procedures that aim to avoid environment noise according to foreseen priorities, to reduce environment noise, to protect from conse-

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quences of its harmful affect, including irritation as well. Directive aims not only to manage noise in strongly influenced territories but also to preserve silence in rather calm areas.

Conception "environment noise" means undesirable or harmful to a person outside sounds that are cased by human activities including noise caused by means of road, railway, air transport and noise from the areas of industrial activities.

Strategic noise mapping in Lithuania is executed implementing the requirements of the Law on Noise Management of the Republic of Lithuania, State Programme of Noise Strategic Mapping, State Programme of Actions of Noise Prevention 2007–2013. In agglomerations where the number of residents exceeds 100 000, noise mapping works are to be done till June 30, 2012.

The aim of the work – while measuring, calculating, and modeling (Oškinis *et al.* 2004; Vasarevičius, Graudinytė 2004; Baltrėnas 2007) to evaluate the spread of motor transport noise in Šiauliai city, to make the maps of motor transport noise, to suggest the means to reduce motor transport noise in the city (Stauskis 2001).

2. Object of the research

General area of city's territory 81.13 km², 18.87 km² of them green areas, 12.78 km² water. There are 16 parks in the city which make 1177 ha. Perimeter of the borders of city's administrational area 70.317 km. Altitudes: water level of the lake Rėkyva 129.8 mabove the sea level, level of the lake Talša 103.0 m, the city center 128.4 m, the mound Salduvė 149.7 mabove the sea level. There are 329 streets (430 street lines) in the city, their total length 297 km, 32% of them with gravel covering. The longest streets: Tilžės St. 9.72 km and Vilniaus St. 5.67 km. Thenumber of main crossroads – 60. Total number of buildings 24 613, number of dwelling houses 10 776 including the buildings that have more than two floors 880 (2006–2007 m. transporto... 2007). There are 123 859 residents who in January, 2008 declared their place of residence in Šiauliai (2006–2007 m. transporto... 2007).

In the city there are 4 gymnasiums, 12 secondary schools, 12 basic schools, 7 primary schools, 9 schools of children's informal education, 29 kindergartens, 18 health and medical treatment institutions (2006–2007 m. transporto... 2007).

The main parameters that motor transport noise depends upon are technical condition of operating means of transport, quality of streets' cover, traffic intensity, driving speed and streets' blockage (Vilniaus visuomenės… 2000). Besides, specific features are characteristic to transport: 1) constantly increasing traffic in the city (5–8% in Šiauliai every year); 2) great concentration of cars in small areas (329 streets, 430 street lines, 60 main crossroads); 3) dynamics of day and night of motor transport traffic (morning and evening rush hours when traffic intensity reaches 2000 and more cars per hour); 4) little possibilities of limiting of auto-mobilization; 5) slow development of streets' network, security of quality of streets' cover (Rimovskis, Ramonas 2005; 2006–2007 m. transporto... 2007).

3. Methods of the research

To describe the impact of motor transport noise we have used noise indexes of day/evening/night L_{DEN} and night L_N, where:

$$L_{DEN} = 10 \lg \frac{1}{24}\left(12\times 10^{\frac{L_D}{10}} + 4\times 10^{\frac{L_E+5}{10}} + 8\times 10^{\frac{L_N+10}{10}}\right),$$

L_D – average long-term A weighted sound pressure level, determined for the day time of one year (12 hours); L_E – average long-term A weighted sound pressure level, determined for evening time of one year (4 hours); L_N – average long-term A weighted sound pressure level, determined for night time of one year (8 hours).

For mapping motor transport noise we have used MapNoise programme module fitted to work in ArcGIS Desktop 9.1 environment. MapNoise software was created in cooperation of companies RAPIDIS and TetraSoft and based on prediction model of noise conditioned by roads' traffic in North countries, which is used to evaluate the impact of traffic upon the environment, projecting and planning the means of noise reduction. In the model each means of transport is evaluated as a separate moving sound source which the amount of noise emission depends upon the type, speed of motor transport, manner of road's cover and traffic conditions. With MapNoise programme the calculations of outlines of noise spread in the investigated territory and calculations of values of noise indexes close to the facades of buildings are performed.

We have performed noise spread calculations in the whole city's territory according to the density of 10 m×10 m calculation points, at 4 m altitude from the ground. For mapping motor transport noise we have used vector map of Šiauliai city (GIS), the data of research of motor transport traffic intensity in the streets of Šiauliai city that were carried out in 2007 by SE Transport and Road Research Institute, and information about the number of residents in the city which was presented by Municipality Information Department (Stanfeld *et al.* 2000).

In order to evaluate the validity of motor transport modeling data we have carried out permanent noise measurements in the central part of the city, in territories of selected, closest to the streets kindergarten "Kregždutė" (address: P. Cvirkos St. 60) and the hospital of Šiauliai region (address: V. Kudirkos St. 82). Uninterrupted noise researches in the environment of kindergarten were performed on July 22–25, and in the environment of the hospital of Šiauliai region on October 14–17.

When performing noise measurements the microphone was installed outside of the building by the distance of 1 m from the facade, at 4 m altitude. We have performed the measurements with the 2nd class digital noise analyser Nor 121, completed with digital level detector, which precision 0.2 dB, the range of measurement from 15 to 140 dB(A). Permanent noise measurements have been carried out with the analyzer working at environment regime. For control purposes we have used 80 dB(A) threshold value of sound recording and record interrupting. We have used NorXfer software to transfer

noise measurement data saved in device's memory (the capacity of hard disk 8 GB) to personal computer.

Using the obtained data, we have calculated the values of noise indexes of day L_{DEN} and night L_N and compared them with the meanings of modeling of motor transport noise near the facades of the mentioned buildings.

The obtained noise modeling and measurement values were compared with the marginal values of noise indexes presented in the Hygiene norm of the Republic of Lithuania HN 33:2007 "Acoustic noise. Noise marginal values in residential and public buildings and their environment" (Table 1).

4. Results of the research of motor transport noise

Fig. 1 presents the data of researches of motor transport traffic intensity in Šiauliai city carried out by Transport and Road Research Institute (2006–2007 m. transporto... 2007). In 2008 we prepared one of constituent parts of the noise strategic map of agglomeration of the municipality of Šiauliai city – motor transport noise maps of present condition (M 1:10000), which are composed of the maps of outlines of day/evening/night L_{DEN} (Fig. 2) and night L_N (Fig. 3) noise indexes and the meanings of these noise indexes near the facades of evaluated buildings.

General noise strategic map of agglomeration of the municipality of Šiauliai city which will consist of revised maps of noise spread of motor transport, railroad, airport and industrial noise, must be prepared and approved till June 30, 2012.

Average annual day and night traffic intensity (AADNTI) in the main streets of the city varied from 7550 to 25 310 cars per 24 hours. The highest traffic intensity has been noticed in parts of Tilžės street between Pramonės and Aukštabalio streets (25 310 cars/day), Aukštabalio and Gardino streets (23 045 cars/day), and Dubijos and Pramonės streets (21 627 cars/day). Referring to AADNTI, the second place is occupied by Architektų street line between Gardino and Aukštabalio streets (22 379 cars/day). The third place is occupied by Žemaitės street line between Dubijos and Vilniaus streets (20 431 cars/day), and in the fourth place there is Pramonės street line between Tilžės and Išradėjų streets (20 287 cars/day). The biggest traffic of freight cars in Tilžės street lines between Pramonės and Aukštabalio streets (4261 cars/day), Aukštabalio and Gardino (3882 cars/day), and Vytauto and Dubijos streets (3415 cars/day). In the street line of Žemaitės street between Dubijos and Vilniaus streets the intensity of trucks was 2816 cars/day, in Architektų street line between Gardino and Aukštabalio streets 2554 cars/day (Triukšmas ... 2000).

According to the data of motor transport noise mapping in Šiauliai city, the highest L_{DEN} noise level (from 65 to 69 dB(A)) among 43 institutions of general education is in the environment of J. Janonis gymnasium, Santarvė and Daukantas secondary schools and Jovaras basic school that are in the central part of the city near to the main streets. In the city there are no kindergartens or health care and medical institutions that would get into L_{DEN} meaning interval exceeding the allowed level L_{DEN} (65 dB(A)).

Altogether in the city there are 539 dwelling houses, in which environment allowed L_{DEN} noise indexes are exceeded. These are the dwelling houses near the main streets in the southern and central parts of the city (Žemaitės, Tilžės, Vilniaus, Dubijos streets and Aušros avenue). In the environment of 50 dwelling houses where 614 persons have declared their place of residence L_{DEN} noise index was exceeded from 5 dB(A) to 10 dB(A).

The number of persons whose houses are affected by L_{DEN} noise exceeding the allowed noise level ($L_{DEN} > 65$ dB(A)) is equal to 8907 and makes 7.2% of all city's residents. The number of persons whose houses are affected by night noise exceeding the allowed noise level ($L_N > 55$ dB(A)) is equal to 38 623 and makes 31.2% (Table 2).

Table 1. Allowed marginal noise values in residential and public buildings and their environment

Name of the Object	Noise level, equivalent noise level, dB(A)	Maximum noise level, dB(A)	Time of the day, hour	Noise marginal values used to evaluate the mapping results of environment noise			
				L_{DEN}	L_D	L_E	L_N
In the environment of residential buildings and buildings of public purpose	65 60 55	70 65 60	6–18 18–22 22–6	65	66	61	55

Table 2. Statistical data of mapping of motor transport noise of Šiauliai city (2008)

Number of persons exposed to noise index L_{DEN} in meaning intervals in their dwellings				
55–59 dB(A)	60–64 dB(A)	65–69 dB(A)	70–74 dB(A)	≥75 dB(A)
30 716	29 870	8 293	614	0
24.8%	24.1%	6.7%	0.5%	0
Number of persons exposed to noise index L_N in meaning intervals in their dwellings				
50–54 dB(A)	55–59 dB(A)	60–64 dB(A)	65–69 dB(A)	≥70 dB(A)
31 369	30 498	8 125	0	0
25.3%	24.6%	6.6%	0	0

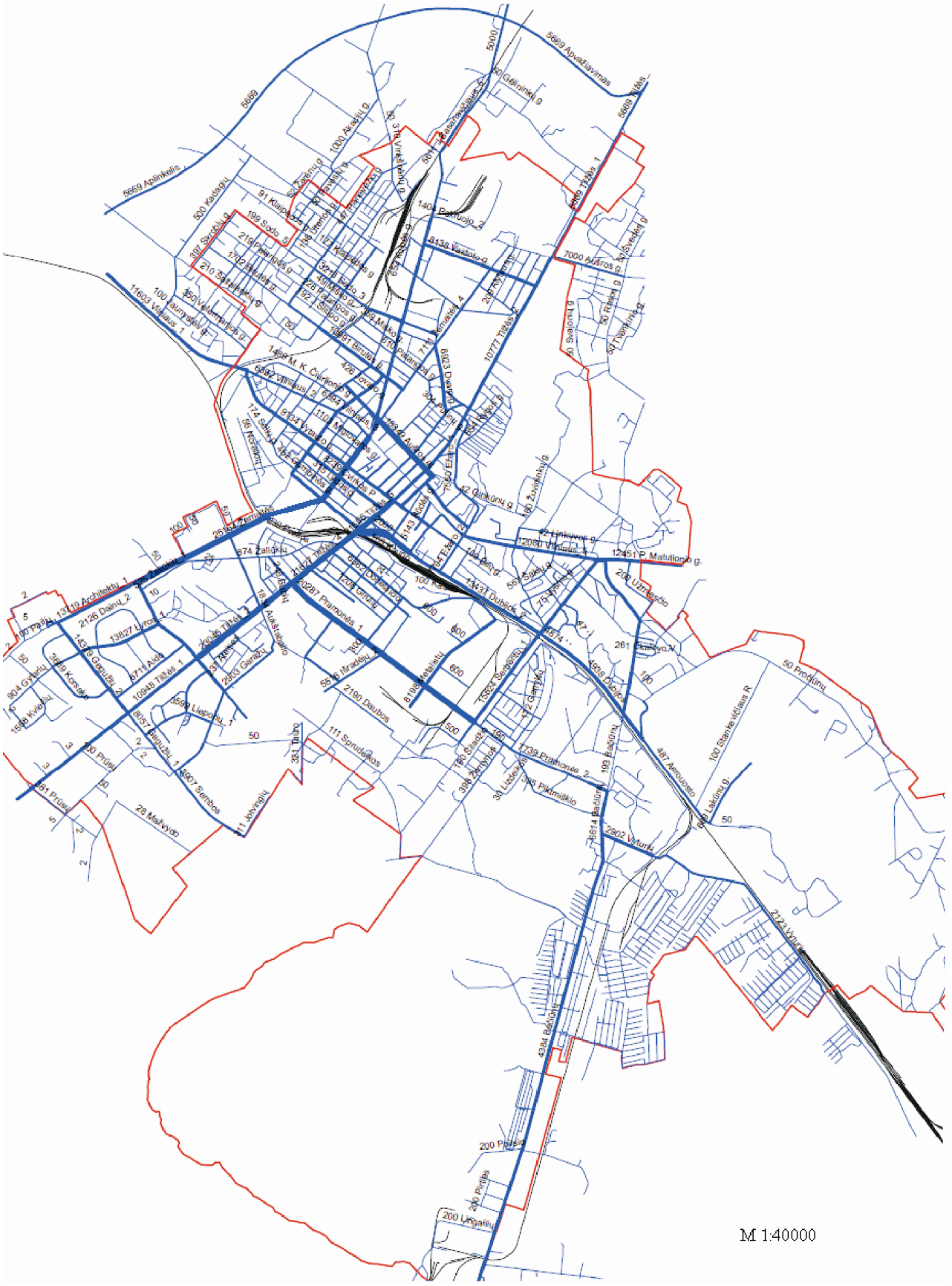

Fig. 1. Road traffic intensity in Šiauliai (2006–2007 m. transporto... 2007)

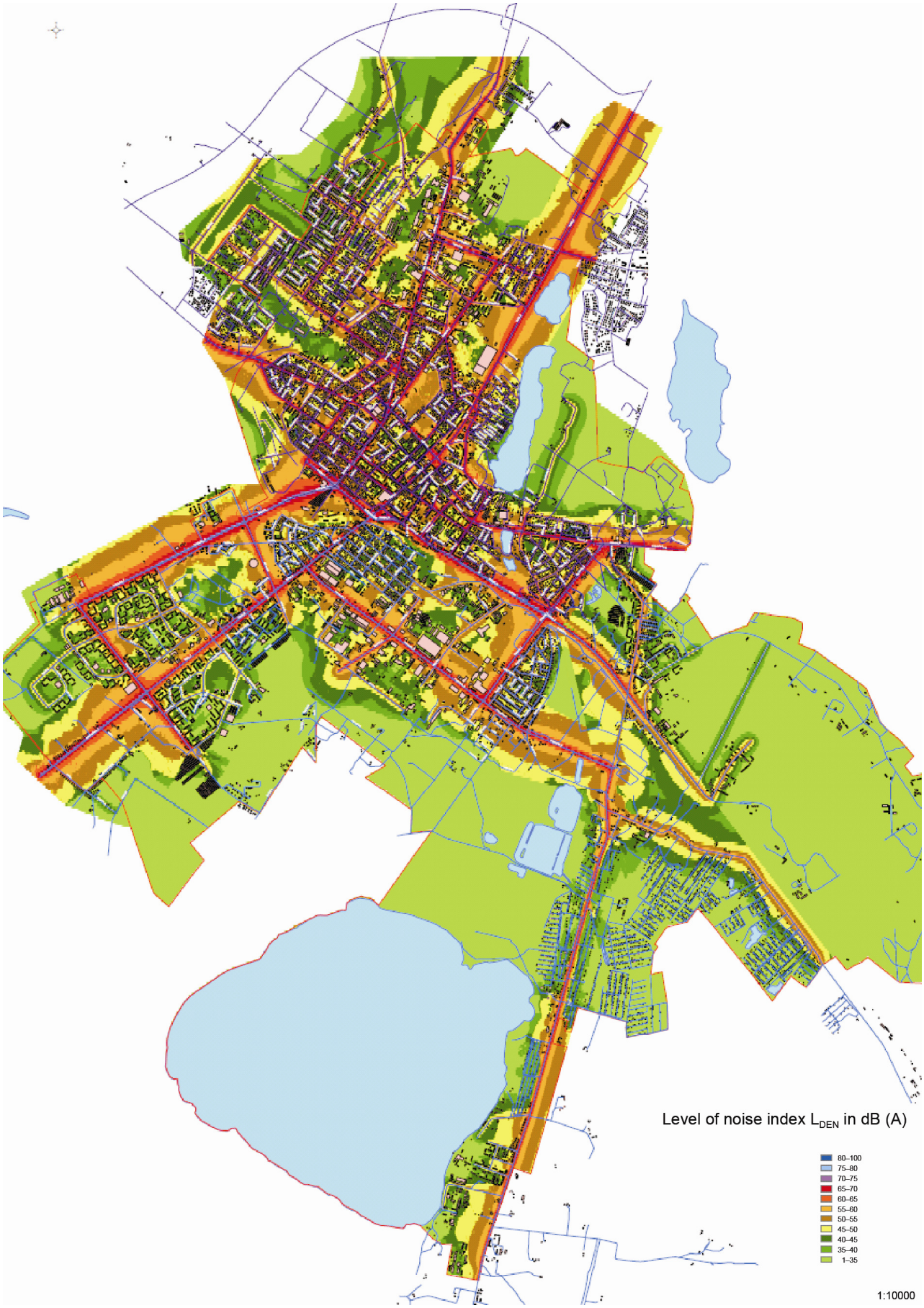

Fig. 2. Map of road traffic noise L_{DEN}

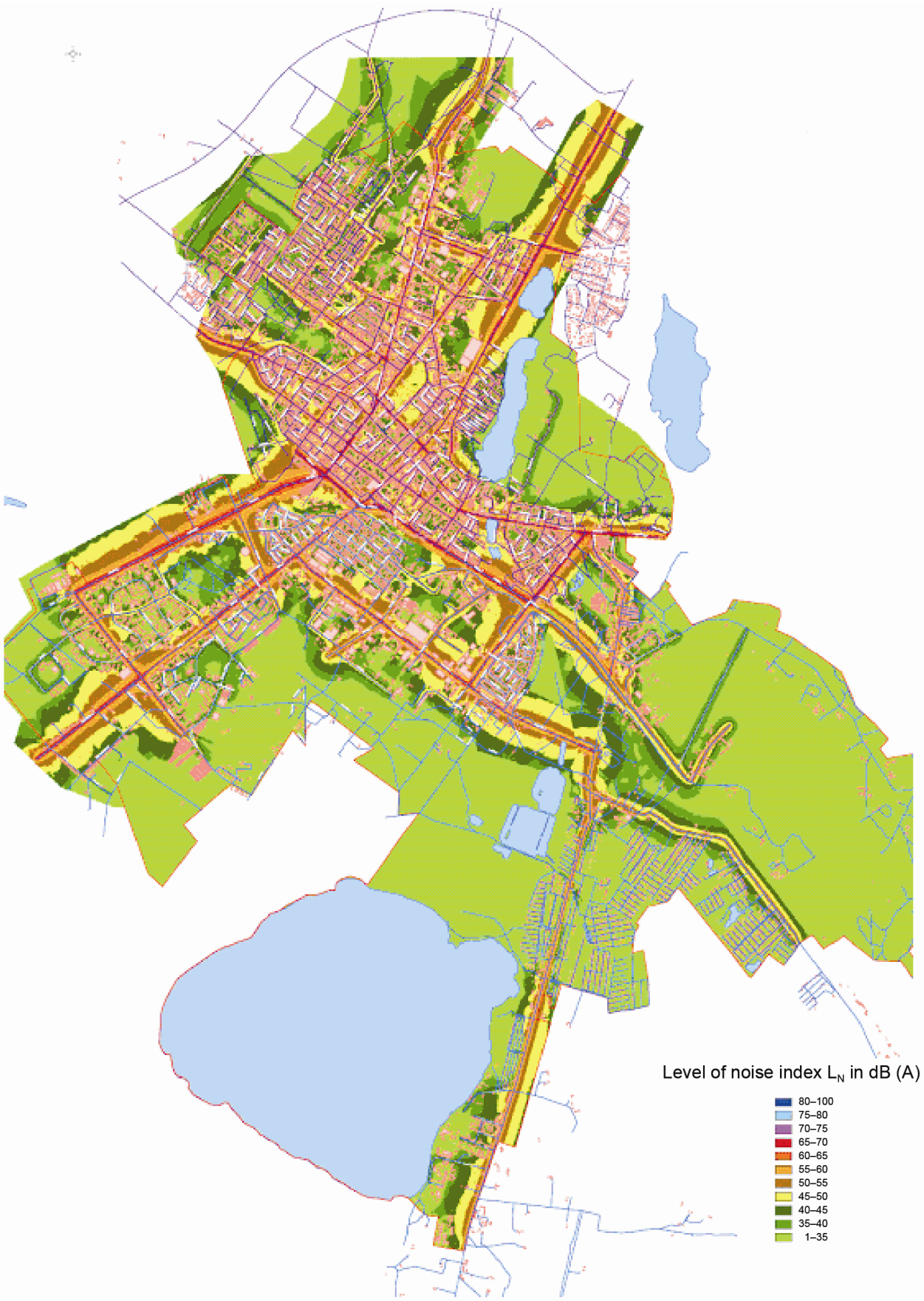

Fig. 3. Map of road traffic noise L_N

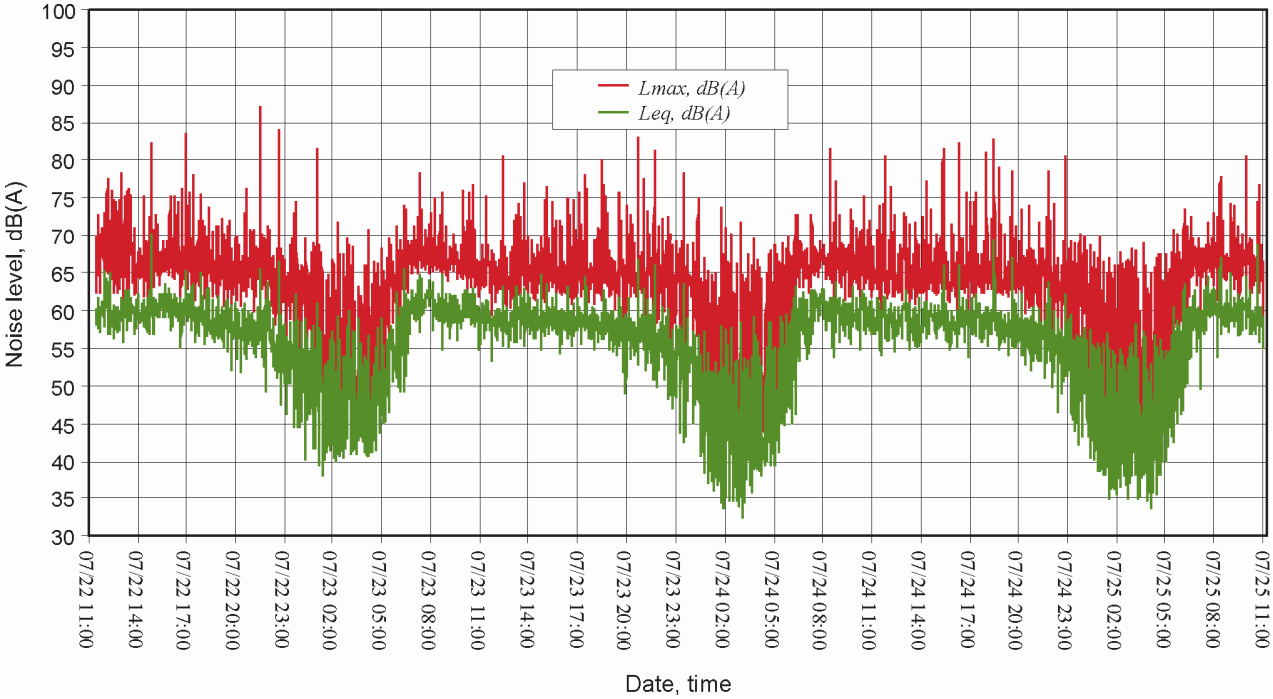

Fig. 4. Change of noise level in the environment of the kindergarten "Kregždutė" on 22–25 July, 2008

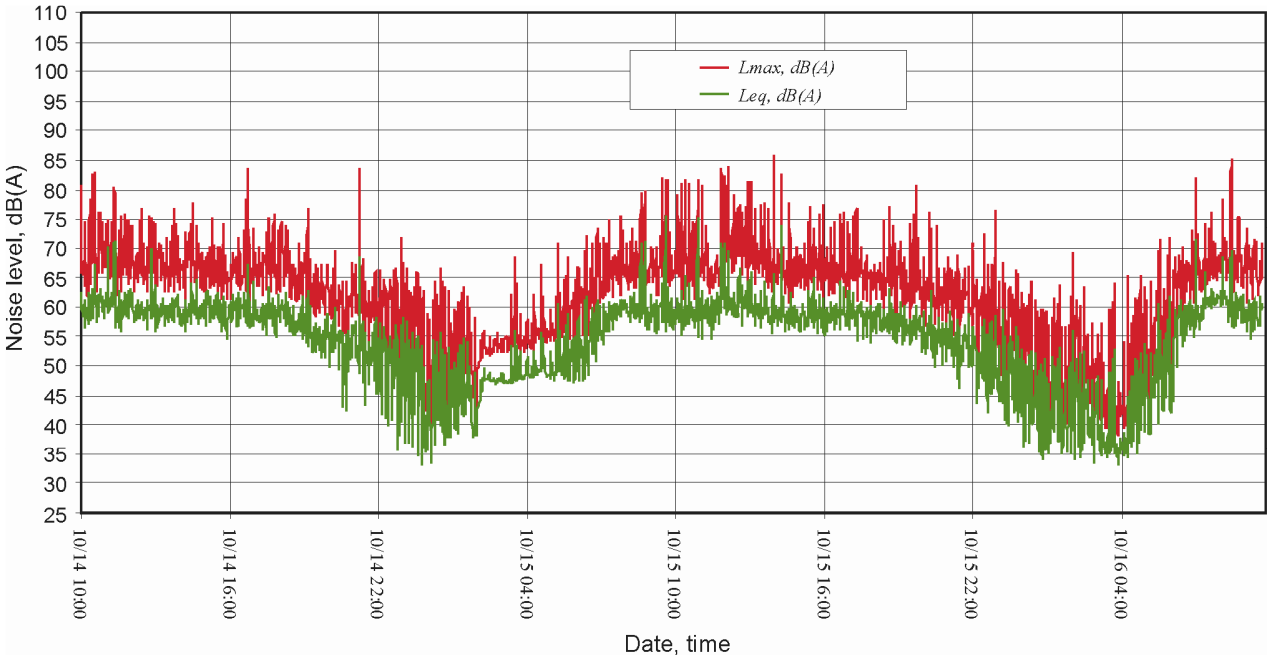

Fig. 5. Change of noise level in the environment of the hospital of Šiauliai region on 14–17 October, 2008

In order to evaluate the validity of motor transport modeling results we have used the data of permanent noise measurements in the environments of kindergarten "Kregždutė" (address: P. Cvirkos St. 60) and the hospital of Šiauliai region (address: V. Kudirkos St. 82) that are in the central part of the city (Figs 4, 5).

According to modeling data, in the environment of the hospital of Šiauliai region the average of day/evening/night noise L_{DEN} is equal to 57.7 dB(A), and the calculated value of measurements – 58.5 dB(A). The difference is 0.8 dB(A) and comprises 1.4%. Modeling value of night noise L_N is 48 dB(A), measurement value – 47.4 dB(A). Difference – 0.6 dB(A) or 1.3% (Table 3).

In the environment of kindergarten "Kregždutė" modeling value of day/evening/night noise is equal to 58 dB(A), measurement value – 58.5 dB(A). Difference is 0.5 dB(A) (0.8%). Modeling value of night noise – 50 dB(A), noise measurement value – 48.9 dB(A). Difference is 1.1 dB(A) or 2.2% (Table 3).

Table 3. Comparison of the results of modeling and measuring motor transport noise in the central part of the city

In the environment of the hospital of Šiauliai region				
	Modeled, dB(A)	Measured, dB(A)	Error, dB(A)	Error, %
L_{DEN}, dB(A)	57.7	58.5	0.8	1.4
L_N, dB(A)	48.0	47.4	0.6	1.3
In the environment of kindergarten "Kregždutė"				
	Modeled, dB(A)	Measured, dB(A)	Error, dB(A)	Error, %
L_{DEN}, dB(A)	58.0	58.5	0.5	0.8
L_N, dB(A)	50.0	48.9	1.1	2.2

Mismatch between the results of modelling and measuring of day/evening/night and night noise in the central part of the city does not exceed 2.2% and varies from 0.5 dB(A) to 1.1 dB(A), therefore, motor transport mapping data is statistically reliable and may be used for evaluation of environment quality of the city.

5. Conclusions

1. The highest day noise level (L_{DEN}) (from 65 to 69 dB(A)) among 43 institutions of general education is in the environment of J. Janonis gymnasium, Santarvė and Daukantas secondary schools and Jovaras basic school that are in the central part of the city near to the main streets.

2. In the city there are no kindergartens or health care and medical institutions that would get into L_{DEN} meaning interval exceeding the allowed 65 dB(A) level.

3. In the city there are 539 dwelling houses, in which environment allowed day or night noise indexes are exceeded. These are the dwelling houses near the main streets in the southern and central parts of the city (Žemaitės, Tilžės, Vilniaus, Dubijos streets and Aušros avenue).

4. In the environment of 50 dwelling houses where 614 persons have declared their place of residence day noise index was exceeded from 5 dB(A) to 10 dB(A).

5. The number of persons whose houses are affected by day noise exceeding the allowed noise level (L_{DEN} >65 dB(A)) is equal to 8907 and makes 7.2% of all city's residents.

6. The number of persons whose houses are affected by night noise exceeding the allowed noise level (L_N >55 dB(A)) is equal to 38 623 and makes 31.2% of all city's residents.

7. Mismatch between the results of modelling and measuring of day and night noise in the central part of the city does not exceed 2.2% and varies from 0.5 dB(A) to 1.1 dB(A), therefore, motor transport mapping data is statistically reliable and may be used for evaluation of environment quality of the city.

Recommendations

We suggest to implement the following means for managing environment noise in Šiauliai city:

1. In accordance with noise modelling data, to prepare the study of usage opportunities of the most effective motor transport noise reduction means (urban, technological, constructional, and administrational) in the areas (to develop renovation of apartament buildings, kindergarten, school, health care and medical institution buildings) that exceed allowed noise level.

2. To develop the system of circuit roads of the city (by the detour section of south and east,in the directions of Vilnius and Riga), to set up underground, multistoreyed, computerized car parking lots.

3. To limit intensity of motor transport traffic (in the section of Tilžė street and Aušra avenue, as well as in the section of Ausra avenue between Tilžė and Žemaitė streets) distinguishing traffic lines only for public transport and to prepare the study of electrical (trolleybuses) in the infrastructure of city's publik transport.

4. To remove industrial building and equipment of industrial purpose ("Rūta", "Verpstas", "Elnias") from the central part of the city (to the planned industrial park).

5. To distinguist and approve public silent areas in the territory of Šiauliai city (in the territory of kindergartens, schools, health care and medical institutions and parks of Dainai and Lieporiai microdistricts) and perform noise level control there.

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AUTOTRANSPORTO TRIUKŠMO SKLAIDOS ŠIAULIUOSE MODELIAVIMAS

L. Paulauskas, R. Klimas

Santrauka

Sparčiai vykstant urbanizacijos procesui, kinta įvairių šaltinių keliamo triukšmo lygis, didėja neigiama įtaka žmonių sveikatai. Miestų aplinkoje iki 80 % visuminio visų triukšmo šaltinių poveikio tenka autotransporto keliamam triukšmui. Straipsnyje pateikta autotransporto triukšmo sklaidos Šiauliuose modeliavimo rezultatai, autotransporto triukšmo žemėlapiai, aplinkos triukšmo valdymo rekomendacijos. Autotransporto triukšmui modeliuoti naudotas *MapNoise* programinis modulis, pritaikytas darbui *ArcGIS Desktop* 9.1 aplinkoje. Iš rezultatų matyti, kad 7,2 % visų miesto gyventojų būstų yra veikiami paros triukšmo, viršijančio leidžiamąjį triukšmo lygį (L_{DVN} > 65 dB(A)), ir 31,2 % gyventojų būstų veikiami nakties triukšmo, viršijančio leidžiamąjį triukšmo lygį (L_N > 55 dB(A)). Įvertinus modeliavimo rezultatų patikimumą nustatyta, kad paros ir nakties triukšmo modeliavimo ir matavimo rezultatų neatitiktis neviršija 2,2 % ir svyruoja nuo 0,5 dB(A) iki 1,1 dB(A).

Reikšminiai žodžiai: triukšmo tyrimai, transporto triukšmas, triukšmo rodikliai, autotransporto triukšmo žemėlapis, triukšmo modeliavimas.

МОДЕЛИРОВАНИЕ РАССЕЯНИЯ ТРАНСПОРТНОГО ШУМА В ГОРОДЕ ШЯУЛЯЙ

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Резюме

При быстром росте урбанизации увеличивается уровень шума, создаваемого разными источниками и отрицательно влияющего на здоровье населения. Шум от автотранспорта в городах составляет около 80% от всех источников шума. В статье представлены результаты моделирования рассеяния шума от автотранспорта в городе Шяуляй, карты автотранспортного шума, рекомендации по управлению шумом в окружающей среде. При измерении шума был использован числовой анализатор шума № 121, укомплектованный с числовым детектором уровня RMS. Для передачи данных в персональный компьютер использована программа NorXfer. Для моделирования автотранспортного шума использован программный модуль MapNoise, приспособленный для работы в среде ArcGIS desktop 9.1. При анализе достоверности результатов моделирования было установлено, что их отличие от результатов измерения шума в течение суток и ночное время не превышает 2,2% и колеблется от 0,5 дБ(А) до 1,1 дБ(А). Результаты исследования свидетельствуют о том, что 7,2% жилых помещений города подвергаются суточному шуму, уровень которого превышает допустимый (L_{DVN} > 65 дБ(А)) и 31,2% жилых помещений города подвергаются шуму в ночное время, уровень которого превышает допустимый (L_N > 55 дБ(А)).

Ключевые слова: исследования шума, автотранспортный шум, показатели шума, карта автотранспортного шума, моделирование шума.

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