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INFLUENCE OF TRUCK TRAFFIC ON ACOUSTIC POLLUTION IN KAUNAS DISTRICTS CROSSED BY HIGHWAYS

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Abstract. The aim of the study was to assess the influence of truck traffic on acoustic pollution in two Kaunas districts crossed by highways- Eiguliai and Šilainiai. Composition of traffic flow and noise measurements were conducted near the main streets and national highways that cross the districts. GIS and statistical software SPSS 12.01 were used for the data analysis. The study results showed that mean noise level near the main streets was 70 dB(A) in the daytime,– 68.6 dB(A) in the evening and at night it was 61.1 dB(A) in Eiguliai, and in Šilainiai it was 67 dB(A), 65 dB(A) and 58 dB(A), correspondingly. On the highways, crossing the districts, heavy vehicles compose about 3 times higher part of total traffic flow during the day and about 2 times in the evening compared to other main streets. The noise level depended on the traffic flow and correlation coefficient fluctuated from 0.77 to 0.85. The modelling of traffic flow showed, that the increase of trucks proportion by 2 percent would increase the traffic noise by 1.1 dB(A) in the streets with traffic flow of 300 veh./hour or more, and by 1.8 dB(A) with traffic flow of 200 veh./hour or less. Our findings suggest that the influence of heavy vehicles on acoustic pollution is higher in the districts with lower traffic flow.

Keywords: environmental noise level, road traffic flow, modelling of changes, heavy vehicles.

1. Introduction

Environmental noise, caused by traffic, industrial and recreational activities, is considered to be a significant local environment problem in Europe. During the recent years citizens' complains about the level of noise have been constantly increasing. The major reason of growing environmental noise is the increasing number of vehicles (some of these being in bad technical condition) (Baltrėnas *et al.* 2004; Žeromskas 1998). Vehicles are the major environmental polluters in Lithuania and other countries (Baltrėnas *et al.* 2004; Kosten ... 1990), thus having a negative influence on the environment and its components (Henckens *et al.* 2000). Motor transport is a source of specific and dynamic pollution penetrating into the living areas, public buildings and other personal environment (Klibavičius 1998). Approximately 60–80 percent of noise level in cities results from traffic (Van Maarseveen, Zuidgesst 2003; Mačiūnas 1999). Most citizens are exposed to traffic noise not only in the streets, but also in their working and leisure areas. Noise in industrial districts is one of the main factors, which decreases quality of life (The Canadian ... 2007).

Traffic flow was continually growing during the last decade; herewith traffic noise has increased approximately by 10–12 dB(A) (Mačiūnas 1999**).** Fast increase of traffic noise has negative effect on health (Sobotova *et al.* 2006), because the increase of noise level by 10 dB(A), people realize as two-times higher noise level.

About 40% of the population in the European Union are exposed to road traffic noise with an equivalent sound pressure level (Leq) exceeding 55 dB(A) in the daytime, whereas 20% suffer from noise level above 65 dB(A) (Jakovljevic *et al.* 2006), which scientists and health experts consider being unacceptable and health damaging (Jarup *et al.* 2005; Future … 1996).

Permanent noise is considered as a factor which increases stress and annoyance (Bluhm *et al.* 2004). Biological indicators of the early noise effects could be apparent through alterations in blood pressure and later one increased myocardial infarction risk (Grazuleviciene *et al.* 2004, 2005). Therefore, noise is one of the environmental agents which can cause environment-related health risks.

Traffic noise in main city streets persists continually high for 1500 to 1800 hours and noise level decreases for a short period of time when the traffic lulls at night. The main noise sources of motor transport are engines, power and movement transmission mechanisms, also quality of pavement, vehicle speed and traffic flow intensity greatly influence noise level. The motor vehicle intensity is the main factor of noise level in the city (Mačiūnas 1999). The highest traffic flow is in the downtown and central streets and also on the highways, which connect living and industrial areas. The main part of traffic flow in industrial city areas, where new buildings are being constructed, take heavy vehicles (63–89 percent), motorcars and public vehicles in living areas (Mačiūnas 1999).

The central part of Kaunas city, where administrative, commercial and cultural activities take place, has been heavily affected by intensive traffic flows. The traffic jams have become an endemic feature of the city cen-

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tre due to insufficient street capacity. Majority of the 3–5-storage buildings situated in the city centre aggregate structures directly exposed to traffic noise (Kliučininkas, Šaliūnas 2006). The US Department of Transportation Federal Highway Administration proposes that 2000 vehicles per hour sound twice as loud as 200 vehicles per hour (U.S. Department … 2007). High speed also affects traffic noise: vehicle which goes 90 kilometres per hour sounds twice as loud as the vehicle which goes 30 kilometres per hour. Assessment of the influence of trucks on the acoustic pollution of highways, crossing the suburbs of the city, could produce the real local data for action plans and noise control through legislation.

The aim of our study was to assess the influence of heavy traffic on acoustic pollution in Kaunas suburbs which are crossed by the national highways.

2. Methods

The study was conducted in two suburbs in Kaunas-Eiguliai and Šilainiai, situated along the national highway. The research group used the Kaunas Municipality data base on noise level measurements in their study. The measurement of traffic flow intensity and noise level in the Kaunas districts were carried out close to the main districts streets in spring of 2007. The traffic flow measurements were carried out in 34 places. Using the cluster analysis methods we attributed the same noise level to the streets, where traffic flow intensity fluctuated less than 20 percent and the number of street lanes was the same.

Vehicles were classified into five categories: cars and minibuses, buses, trolleybuses, heavy vehicles (trucks), and motorcycles.

Traffic flow was studied in some main streets of Eiguliai (Šiaurės pr., Sukilėlių pr., Ašigalio str. and other) and Šilainiai (Vandžiogalos g., Baltų g., Baltijos g.) districts and on two highways (Islandijos road and Vakarinis detour).

According to the used statistical noise models, traffic flow was evaluated like linear noise source, which can send variable noises and the traffic flow period turn on traffic flow value in two directions. In the cases when traffic flow value was (Q) 1000–1500 veh./hour, the traffic flow was measured 10 min, when Q>2000 veh./hour – the measurement duration was 6 min, and when Q 500–1000 veh./hour – the period of traffic flow measurement was recommended up to 15 min.

To plot a map of the noise level in the research area, short-term measurements: 15 min. during the day and afternoon time and 30 min. at night time were carried out. The data were calculated for each vehicle per hour Q hour (veh./hour). The traffic flow intensity data were used to simulate noise dispertion.

The measurements of an average traffic flow and noise level were conducted at the same time in the same places based on the actual traffic counts for plotting a map of the streets and gauging the noise level. A precise Sound Meter and a Noise Level Analyzer were used to assess the main sound levels of 15 min. and 30 min. measurements. The data were recalculated into a factual level of noise. The calculation was accomplished applying the Finnish and Swiss methodology employed in their research of transport noise. The methodology was based on an EMPA StL-86 model, using an acoustic algorithm (Heutschi 2004).

The measurements for given streets and districts were then linked to the Geographic Information System (GIS). We also used statistical software SPSS 12.0.1 for data analysis and assessment of the association between traffic flows and noise level. The traffic flow intensity and noise map of Eiguliai and Šilainiai districts was plotted using GIS which provided the possibility to optimize the quality and efficiency of noise studies. Moreover, GIS decreased uncertainties in exposure assessment (Kluijver, Stoter 2003).

3. Results

The results of our study show that traffic flow is the principal environmental noise source having correlation with noise level dimension. The highest traffic flow in the main streets of Eiguliai and Šilainiai districts was during the rush hour in the day and evening. The mean hourly traffic flow was 730 veh./hour in the daytime, 520 veh./hour in the afternoon, and 85 veh./hour at night in the mean streets of Eiguliai district, and in Šilainiai district it was as follows: 725 veh./hour, 477 veh./hour and 79 veh./hour accordingly. The traffic flow was greatly fluctuating during 24-hours, and it fluctuated less in the daytime during one hour.

The intensity of traffic flow on the national highways, crossing Eiguliai and Šilainiai districts, was 5 times higher in the daytime and 6 times in the evening than in the main streets of Kaunas at the same time.

Traffic flow intensity for 24-hours in the main streets of Eiguliai and Šilainiai districts and on two national highways is shown in Table 1.

It was evident that the biggest part of traffic flow was made by cars and minibuses. The buses in Šilainiai district made 2.99 percent of the flow during the day, 1.94 percent in the evening and 3.23 percent at night. Fewer buses proportion was in Eiguliai district – 2 percent in the daytime and in the evening and 1 percent at night. The highest trucks flow was on the highways: there was 16.47 percent by day, 6.04 – in the evening and 1.22 at night on the national highways. Trucks flow in Eiguliai district was as follows: 4.1 percent, 2.78 percent, and 1.1 percent and in Šilainiai district it was: 8.19 percent, 2.99 percent, and 1.5 percent. The motorcycles and trolleybuses made up about 1 percent of the traffic flow during 24-hours.

The research group studied the relationship between the traffic flow and traffic noise in Eiguliai and Šilainiai districts during 24-hours. The findings suggest the relationship or the correlation coefficient between traffic flow and traffic noise in Eiguliai district being 0.85 by day and evening and 0.83 at night, and in Šilainiai district – 0.78, 0.77, and 0.80 accordingly (Fig. 1).

Public transport and motorcars in Kaunas are noisier in comparison with aged vehicles in other European Union countries, because the average motorcars' age in Kaunas is more than 13 years. It was shown that new

model public vehicles are approximately by 8–10 dBA quieter than old public vehicles, which are used in Kaunas. Medium heavy vehicles in Kaunas are also by 8 dBA noisier than heavy vehicles in Denmark, Sweden, Germany or other EU countries (Kliučininkas, Šaliūnas 2006). Therefore, lower traffic flow in Lithuania emits more noise than the same traffic flow in other EU countries.

Our data show, that the average equivalent 24-hours noise level depends on the average equivalent traffic flow. Highest traffic intensity was stated in the main streets of Eiguliai and Šilainiai districts and on both national highways, where 20,000–30,000 vehicles passed during 24-hours. The highest noise level was also stated there (Fig. 2).

Noise level in the major streets of Eiguliai and Šilainiai districts exceeded the limits for sleeping areas. The average equivalent noise level in the daytime (6:00–18:00 hour) in Eiguliai district was found to be 70 dB(A) (allowable noise level 65 dB(A), in the evening (18:00–22:00 hour) – 68,6 dB(A) (allowable noise level 60 dB(A)), and at night time (22:00–6:00 hour) – 61.1 dB(A) (allowable noise level 55 dB(A)). The average equivalent noise level by day in Šilainiai

Table 1. Composition of road traffic flows (in percentage) per hour

Motor vehicle	Day 6:00–18:00 h			Evening 18:00–22:00 h			Night 22:00–6:00 h		
	Eiguliai N = 757	Šilainiai N = 652	Highways N = 3906	Eiguliai N = 541	Šilainiai N = 424	Highways N = 2648	Eiguliai N = 89	Šilainiai N = 145	Highways N = 632
Cars and mini buses	92.7%	88.77%	81.75%	94.26%	95.04%	92.22%	97.8%	95.18%	97.46%
Buses	2.24%.	2.99%	1.58%	2.04%	1.94%	1.74%	1.1%	3.23%	1.32%
Trolleybuses	0.92%	0%	0%	0.92%	0%	0%	0%	0%	0%
Trucks	4.1%	8.19%	16.47%	2.78%	2.99%	6.04%	1.1%	1.5%	1.22%
Motorcycles	0.04%	0.04%	0.2%	0%	0%	0%	0%	0.15%	0%

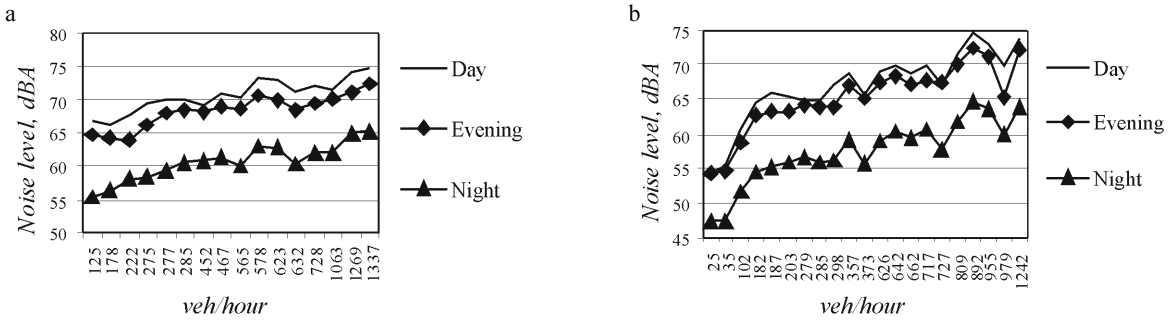

Fig. 1. Traffic flows and their noise levels in Eiguliai (a) and Šilainiai (b) districts during different daytime periods

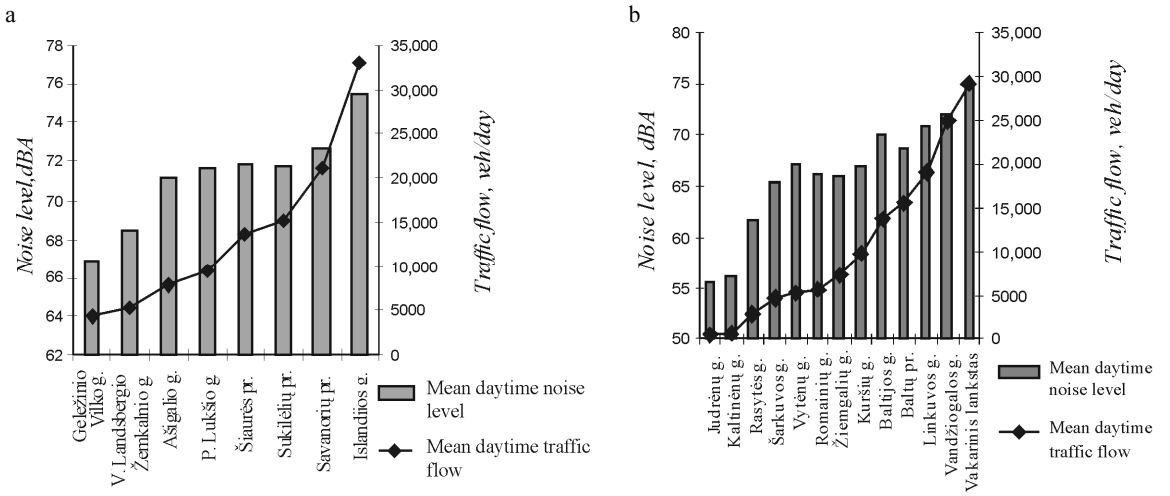

Fig. 2. Mean daytime noise levels and mean daytime traffic flows on major streets in Eiguliai (a) and Šilainiai (b) districts

district was 67 dB(A), in the evening – 65 dB(A), and at night time – 58 dB(A). So noise level during the daytime exceeds the limits by 8 percent, in the evening – by 12 percent and at the night – by 10 percent.

The peak of noise level in the daytime was 74.7 dB(A), in the evening – 72.3 dB(A), and at night time – 65.3 dB(A) and it exceeded the daytime limits by 6 percent, evening – by 10 percent, night – by 8 percent.

Most living houses in Eiguliai and Šilainiai districts are located only 50 meters away from the main streets. In such distance noise level exceeded the limits of about 10 percent during the 24-hours period. Although the noise level in the housing forecourts didn't exceed the allowable noise level.

The study analyzed the trucks contribution to general environmental noise in several areas and modelled changes of noise levels in different Kaunas city districts. It was found that heavy vehicles' input to noise level is higher when traffic is low. The contribution of trucks to noise in the general environment decrease with increasing traffic flow.

Using the logistical regression equation variation of the noise level we can forecast, that when traffic flow is growing, an increase of trucks by 2 percent will increase in traffic noise by 1.1 dB(A) in the streets in Kaunas with the traffic flow of 300 veh./hour or more (correlation coefficient – 0.63), and it will increase noise by 1.8 dB(A) in the streets with the traffic flow of 200 veh./hour or less (correlation coefficient – 0.68). Our data show that traffic flow increase by 25 percent results in the increase of noise level by 1.5 dB(A).

The growing environmental noise is associated with a rising number of vehicles where the growth of heavy vehicles has the largest impact. Acceleration of speed and peculiarities of interaction between tires and road surface are also known as the factors influencing the level of noise.

The traffic flow and noise maps of Eiguliai and Šilainiai districts were plotted by GIS in order to show the noisiest zones of these districts (Figs 3 and 4).

The growth of the traffic flow and trucks proportion on the highways shows the rise in the noise level near the housing sector.

The level of traffic noise also depends on the number of trucks in the traffic flow, vehicles' state, weight and speed of each vehicle. One truck, which goes 90 kilometres per hour, makes the same noise like 28 cars, which go at the same speed (U.S. Department ... 2007). There are two streets in Kaunas city (Islandijos road and Vakarinis detour) which are joined to the national road system. It is forecasted that traffic flow in these highways will grow, the noise level in Eiguliai and Šilainiai districts will also increase if effective road traffic noise management policy is not implemented.

The growing traffic flow requires finding some noise reduction ways as it is very important to the people who live near busy main streets (Baublys *et al.* 2003). Environmental noise, caused by traffic, industrial and recreational activities, is one of the main environmental problems and the source of an increasing number of complaints from the local population. The European Commission has recognized the importance of monitoring of noise exposure, and also acknowledged the necessity of substantive investigations for appropriate policies to control noise through legislation. The main goal of the local action is to reduce noise to the level which is safe to human health. (Kaminskas 2001).

Acoustic barriers, typically reducing noise levels from 10 to 15 decibels and cutting the loudness of traffic noise in half, is a very effective device to protect some territory from noise (Verkehrsbedingte … 1991). Noise level in the living area without barriers would be 63 dBA, and with 8 meter high barrier 55 dBA (Baltrėnas *et al.* 2007). Dense vegetation in width of 60 meters can reduce noise level up to 10 decibels cutting in half the loudness of traffic noise. However, it is often impractical to plant enough vegetation along a road to achieve such reductions (U.S. Department … 2007).

Achieving an effective road traffic noise policy requires above all a concerted approach that balances the need to reduce road-related sound emission without affecting mobility and its associated socio-economic benefits. The environmental monitoring data in the EU countries, covering the past 15 years, do not show significant improvements in exposure to environmental noise especially road traffic noise, so in Lithuania as well. The growth of traffic flow and spread of traffic in space and time, development of leisure activities and tourism have partly offset the technological solution (Future ... 1996). There is a need for more research, but also a need to begin to explore policy options that will protect the exposed population.

4. Conclusions

1. The average equivalent noise level in Kaunas districts, crossed by national highways was as follows: in Eiguliai district –70.0 dB(A) in the daytime, 68.6 dB(A)in the evening, 61.1 dB(A) at night and in Šilainiai district it was 67.0 dB(A), 65.0 dB(A), and 58 dB(A) correspondingly.

2. The intensity of traffic flow on the national highways, crossing Eiguliai and Šilainiai districts, was 5 times higher during the day and 6 times in the evening, while trucks proportion compose about 3 times in the daytime and about 2 times in evening time higher part of total traffic flow than in the other main streets of Kaunas.

3. There is a relationship between the traffic flow and the environmental noise level: the correlation coefficient in Eiguliai district was 0.77 and in Šilainiai district it was 0.85.

4. Using logistical regression equation variation of noise level we can forecast, that with the growth of the traffic flow, increase of truck proportion by 2 percent will result in the rise of traffic noise by 1.1 dB(A) on the streets with traffic flow of 300 veh./hour or more, and increase in noise by 1.8 dB(A) on the streets with traffic flow of 200 veh./hour or less. Heavy transport's influence on acoustic pollution is higher in the districts with lower traffic flows.

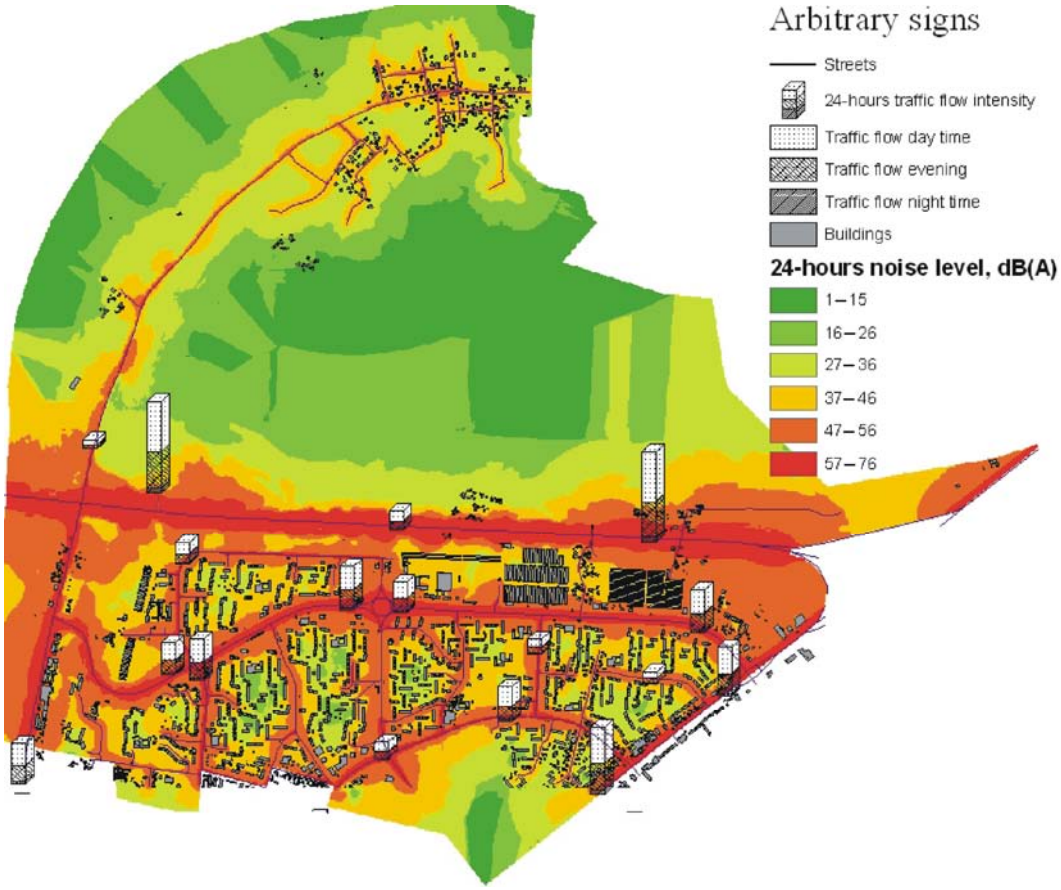

Fig. 3. Traffic noise spread from magistral roads in Eiguliai district

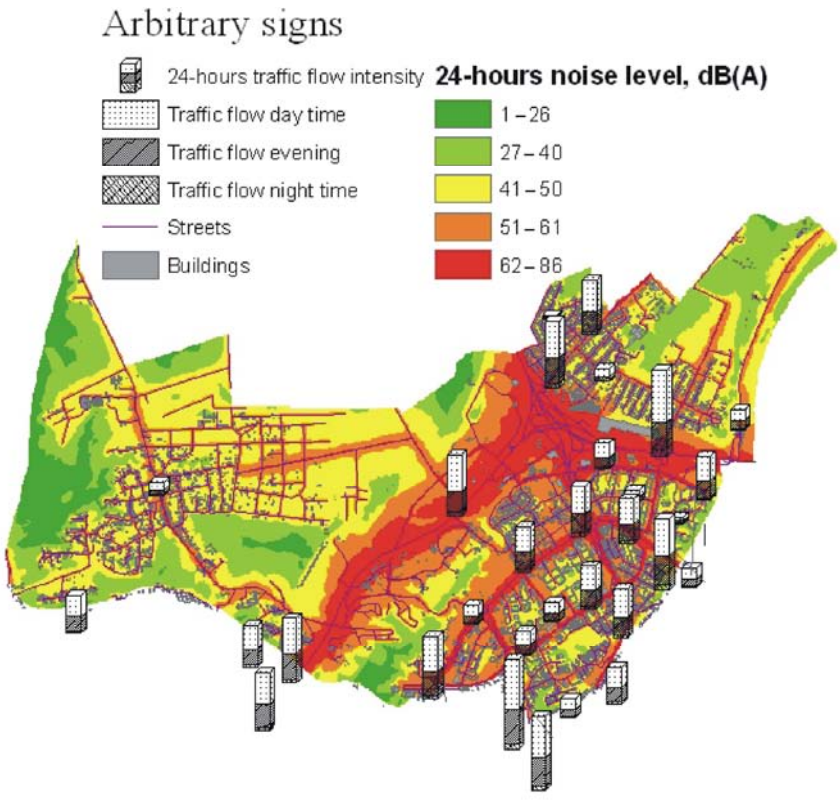

Fig. 4. Traffic noise spread from magistral roads in Šilainiai district

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KROVININIO AUTOTRANSPORTO ĮTAKA AKUSTINEI TARŠAI RESPUBLIKINĖS REIKŠMĖS MAGISTRALIŲ KERTAMUOSE KAUNO MIKRORAJONUOSE

R. Gražulevičienė, I. Bendokienė

Santrauka

Tyrimo tikslas – nustatyti krovininio autotransporto įtaką akustinei taršai Kauno mikrorajonuose, kuriuos kerta respublikinės reikšmės magistralės – Islandijos plentas ir vakarinis lankstas. Aplinkos triukšmo lygis ir transporto srautų intensyvumas Eigulių ir Šilainių seniūnijoje buvo matuotas 34 taškuose – dieną, vakare ir naktį. Duomenims apdoroti taikyta geografinių informacinių (*GIS*) sistemų technologijos, *SPSS 12.0.1* ir *Statistica 15* statistinės analizės paketai.

Tyrimų rezultatai: vidutinis ekvivalentinis triukšmo lygis Eigulių seniūnijoje dieną prie pagrindinių gatvių siekė 70 dBA, vakare – 68,6 dBA, o naktį – 61,1 dBA ir iš esmės nesiskyrė nuo Šilainių seniūnijos, atitinkamai 67 dBA, 65 dBA ir 58 dBA. Magistraliniuose keliuose, kertančiuose Eigulių ir Šilainių seniūnijas, vidutinis transporto srautų intensyvumas dieną ir vakare buvo 5 kartus, naktį 6 kartus didesnis nei vidutinis srautų intensyvumas pagrindinėse gatvėse tuo pačiu metu, o krovininio autotransporto dalis dieną 3 kartus, o vakare 2 kartus viršijo vidutinius pagrindinių gatvių srautus. Nustatyta sąsaja tarp transporto srautų intensyvumo ir triukšmo lygio: Eigulių seniūnijos dienos koreliacijos koeficientas buvo 0,85, vakaro ir nakties – 0,83, o Šilainių seniūnijos – atitinkamai 0,78, 0,77 ir 0,80. Transporto srautų sudėties modeliavimo duomenimis, padidėjus krovininio transporto proporcijai 2 %, gatvėse, kuriose transporto srautas didesnis nei 300 aut./val., triukšmo lygis padidėtų 1,1 dBA, o kur transporto srautas mažesnis nei 200 aut./val., triukšmo lygis padidėtų 1,8 dBA (koreliacijos koeficientas – 0,63). Krovininio transporto įtaka akustinei taršai didesnė mikrorajonuose, kuriuose transporto srautai nedideli.

Reikšminiai žodžiai: aplinkos triukšmo lygis, autotransporto srautai, kitimų prognozavimas, krovininis transportas.

ВЛИЯНИЕ ГРУЗОВОГО АВТОТРАНСПОРТА НА АКУСТИЧЕСКОЕ ЗАГРЯЗНЕНИЕ В МИКРОРАЙОНАХ ГОРОДА КАУНАСА С ТРАССАМИ ГОСУДАРСТВЕННОГО ЗНАЧЕНИЯ

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Р е з ю м е

Целью данной работы было изучить влияние грузового автотранспорта на акустическое загрязнение в микрорайонах города Каунаса, которые пересекают трассы государственного значения. Это шоссе Исландиос и объезд Вакаринис. Состав транспортного потока определялся и уровень шума измерялся около главных улиц микрорайонов. Результаты исследования показали, что средний уровень шума днем был 70 dBA, вечером – 68,6 dBA, ночью – 61,1 dBA. На трассах государственного значения, пересекающих микрорайоны, по сравнению с другими улицами потоки грузовых автомобилей были в 3 раза больше днем и 2 раза больше вечером. Установлена зависимость между величиной транспортного потока и шума (r = 0,77–0,85). Моделирование состава транспортного потока показало, что при увеличении на улицах грузового транспорта на 2% с 300 авт./час и больше шум увеличивается на 1,1 dBA, а при количестве грузового транспорта, составляющем 200 авт./час и меньше, шум возрастает на 1,8 dBA. Влияние грузового автотранспорта на акустическое загрязнение больше в микрорайонах с небольшим транспортным потоком.

Ключевые слова: окружающая среда, уровень шума, автотранспортные потоки, прогнозирование изменений.

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