

PROTECTION FROM THE ROAD NOISE IN SUBURBAN AND URBAN CITY AREAS IN THE REPUBLIC OF MACEDONIA

Goran I. Mijoski¹, Risto Manchev

¹ Faculty of civil engineering, „Saints Cyril and Methodius“ University - Skopje, Republic of Macedonia, mijoski@gf.ukim.edu.mk

Summary: *The noise has great influence on the environment and represents a serious problem, because it contributes for significant reduction of the life quality of the people. In the order of the influences on the environment the noise is on the very top, together with the pollution of the air and the water. It's very important to point out that the noise has bad influence not only on the environment, but also on the driver and the passengers in the car. Special accent in the paper is put on the noise caused from the motor traffic – so called „traffic noise“, which is dependent from the surface characteristics of the pavement surfaces.*

Key words: *noise, pavement surface, tires, measures for noise protection, acoustic barrier.*

1. INTRODUCTION

The sound presents a kind of energy that gets transferred through sound waves that the human ear can detect (range of sound pressure from 0 to 120 dB, while the human ear can detect sound in the range from 20 Hz to 20 kHz), and noise is defined as all the unwanted sound we hear. Noise has its physical properties: intensity, range and time changes that are measured by specific units. The intensity is measured in decibels [dB], range in frequency [Hz], and the time changes of duration are measured in seconds [s], or parts of a second. Most sources of noise from everyday life can be represented as: dotted and linear sources. The sound from dotted sources spreads monotonous in all directions, while the sound of linear sources spreads cylindrically. Noise coming from road traffic, represents a linear source of sound.

Noise has a major impact on the environment and poses a serious problem because it contributes to a significant reduction in the quality of people life. In the order of influences on the environment, noise is at the very top, along with air and water pollution. Noise affects people in a form of harassment and diseases associated with stress, and also has an impact on the communication and concentration. Also it may cause reduced sleeping and stress, contributes to higher blood pressure and heart disease. Noise of 80 dB is traumatic (work performance, sleep), while physiological changes occur within the noise of 65 dB. The impact of noise on animals is expressed with obstacles in communication, migration and reproduction. Conducted surveys in EU countries showed that nearly 20% or about 80 million inhabitants live and work in areas where noise level is higher than 65 dB, and approximately 170 million inhabitants live and work in so-called "Gray zones" in which the noise level ranges between 55 and 65 dB. (European Commission: *Green Paper – Future Noise Policy*, Brussels, 1996). Based on conducted tests, the European Union recognized noise as a problem, published Directive 2002/49/EC.

As common sources of noise, can be specified: construction activities, road and railway infrastructure, airport or helipad, street infrastructure, parking (open or closed - in an object), buildings for sports and other events, buildings for accommodation and residence of people (neighborhood), household appliances, racing tracks, amusement parks, shooting grounds and other. Based on conducted surveys, the type of noise which is a result of different sources, it was concluded that the greatest percentage of 81% goes to noise caused by traffic called transport noise, while only 19% of noise is a result of other noise sources (industry, construction and noise from activities in their spare time) (Figure 1). There are three types of transportation noise: the noise from road, rail and air traffic.

¹ mijoski@gf.ukim.edu.mk

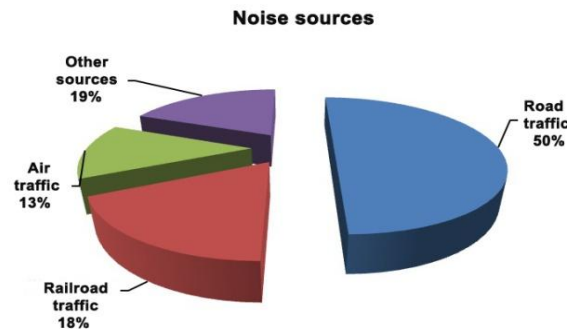


Figure 1. Diagram of percentage share of various noise sources
 Source: (European Commission: Green Paper - Future Noise Policy, Brussels, 1996)

Noise as a serious problem should be considered in all stages of the transport system, from design, construction, maintenance, up to reconstruction. The noise that comes from transport affects millions of people and in many cases requires competent authorities to ensure the reduction of noise from transport, to improve or completely restore their quality of life. Noise impact on the quality of life can be very significant especially when expansion to transport systems. That is why there is a greater need for noise control and why noise in the field of transport is constantly increasing.

2. NOISE ON THE DRIVING SURFACES

Any source of sound can be described thanks to the combined ranges, amplitudes and time history. The range reveals the frequency content of sound. Figure 2 shows an example of the continuous range of constant motorway traffic, where you can see that the most dominant frequency range is between 200 and 2000 Hz.

People do not hear equally well on all frequencies, they are perfectly able to hear frequencies from 20 to 20,000 Hz (though sensitivity at higher frequencies decreases with age), where the hearing is most sensitive from about 1,000 to 6,300 Hz.

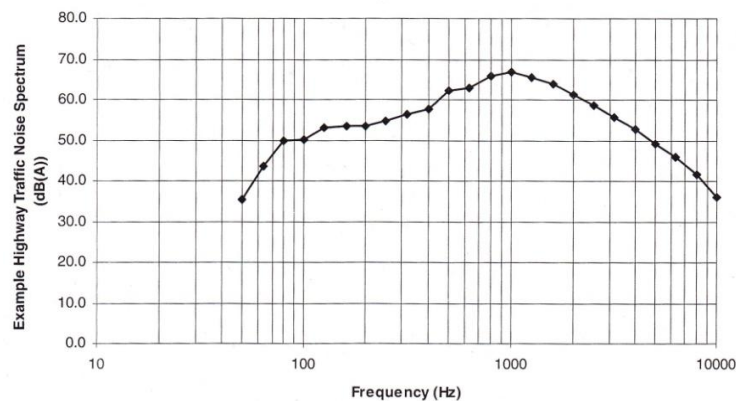


Figure 2. Example of a range from transport noise on motorway
 Source: (Rochat J.L.: Transportation noise issue)

2.1. Influential factors of transport noise

Noise caused by motor traffic called transport noise is the result of interaction between motor vehicles and pavement surface. Changes of the interaction, lead to changes in the level of noise. It depends on the intensity, type, structure and speed, and regarding the way it depends on the type, condition of the pavement surface and longitudinal slope.

Noise caused by motor vehicle in motion, can be divided into

- noise created by the engine when working („**engine**“ noise) and
- noise generated by the interaction of tyres from the vehicle and the pavement surface, when the vehicle is passing through the media - air („**rolling**“ noise)
- noise which is the result of air turbulence that occurs when the vehicle moves („**aerodynamic**“ noise) (Figure 3).

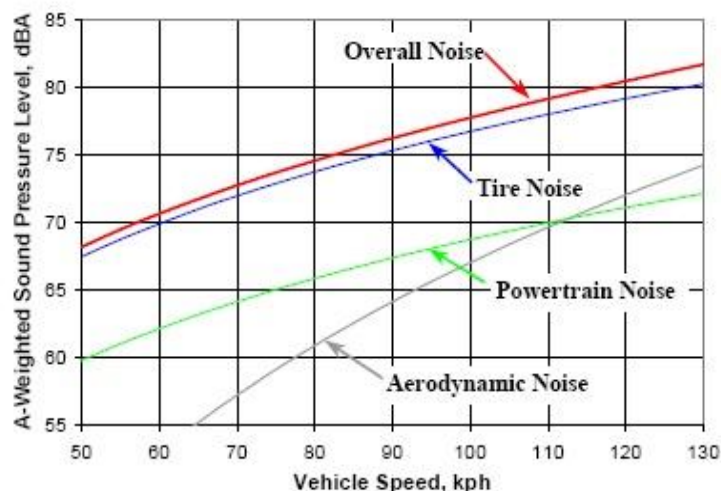


Figure 3. Types of traffic noise

Source: (Rochat J.L.: Transportation noise issue)

The sound that comes from motorway traffic, a distance of about 90 meters (300 feet) from motorways, nearly always presents a noise level of 60 dB (A) (Figure 4).

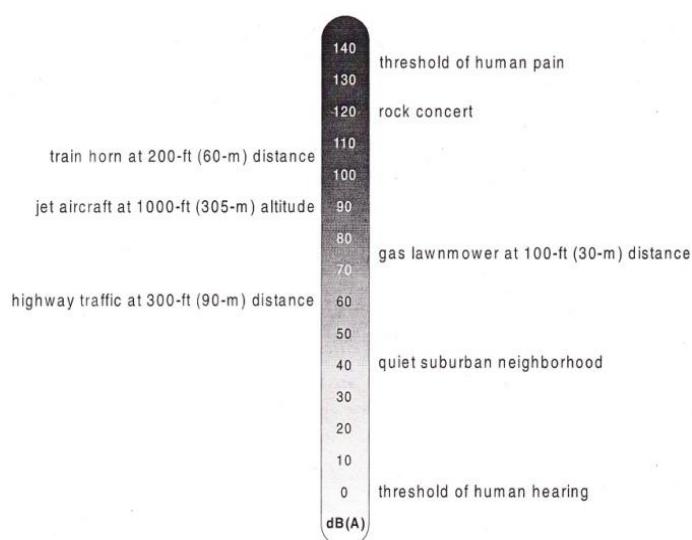


Figure 4. Examples of noise sources

Source: (Rochat J.L.: Transportation noise issue)

2.1.1. Impact of transport noise from pavement surface

The results of measurements of noise during movement on pavement surface from asphalt concrete, show that the noise from the rolling of the tyre in direct speed, is the source of noise which is predominant in lightweight, and in heavy vehicles. This shows that such noise is primarily dependent on structural features of the pavement surface (depth of micro and macrotexture) and bumps or evenness of the pavement surface expressed by the parameter – „International Roughness Index“ (IRI [m/km]). Greatest impact on noise have the pavement surface and the traffic. Pavement surface influences noise through the following factors: roughness and condition of the surface. The influence from the depth of roughness of the pavement surface (Figure 5 & 6) mostly depends on:

- the selected type of wearing asphalt layer (in terms of graininess and composition of the asphalt mixture);
- impacts from construction;
- as well as additional measures taken in the exploitation of roads (procedures thinning the road).

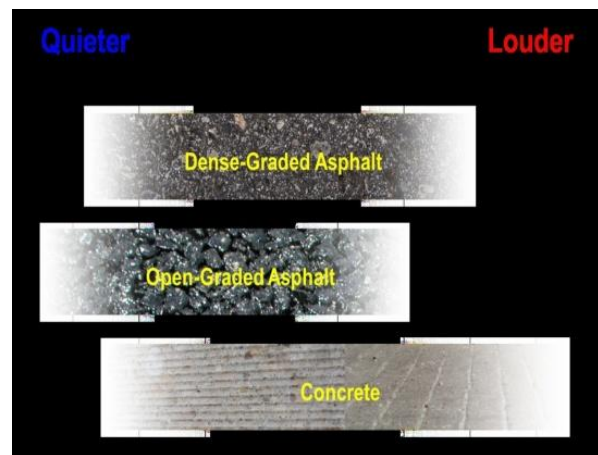
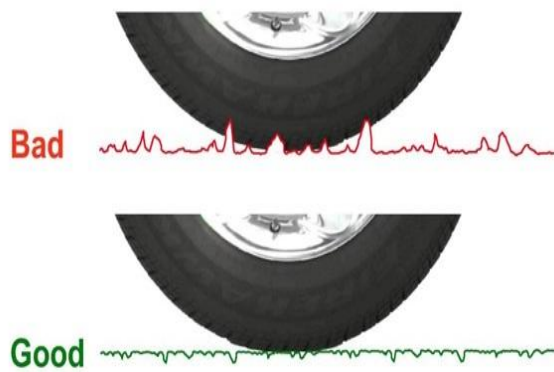


Figure 5. Bad and good texture **Figure 6.** Range of tire-pavement noise levels for various types of pavement
Source: (FHWA: The little book of quieter pavements)

It was found that there is proportional dependence between the depth of surface roughness and the pavement surface, or by increasing the depth of the pavement surface roughness, it comes to a linear increase of the noise and reverse, by reducing roughness noise is reduced from the interaction with tires, but it is important to note that reducing roughness deteriorates the stability of vehicles and requirements for traffic safety. Roads with so-called "positive" texture, make higher noise than those with "negative" texture.

Also, it was determined that the emission of noise on concrete pavement surfaces (with final wearing layers) is greater than the pavement surface of asphalt wearing layers. Influential factor on the increase of noise is the final layer of road depending on the method of calculation, according to the German (Tab. 1) or French method (Tab. 2), its impact is different.

Tab. 1. Increase in the level of noise depending on pavement surface (German method)

Type of pavement surface	D ₄ (dBA)
Asphalt	0
Rough asphalt and concrete	1
Rough concrete (blistered)	1,5 - 2

Source: (doctoral disertation)

Tab. 2. Increase in the level of noise depending on pavement surface (French method)

Type of pavement surface	D _{коловоз} (dBA)
New asphalt or cement concrete pavement	0
Coarse grained asphalt	2
Flat rocky coating, worn cement concrete pavement	3

Source: (doctoral disertation)

Additional external factors that affect the noise are the situation on the pavement surface, or evenness, unevenness, dimensions and geometric elements of the alignment (longitudinal and cross slope, horizontal and vertical curvature of the route), then emerging deformations of it, its polishing whether pavement surface is dry or wet (Tab. 3) and others.

Tab. 3. Average values measured on noise at asphalt and concrete vehicular structures for specific situations on the road

Wearing layer	Condition of the road	Speed of driving (km/h)		
		60	80	100
		Noise in [dB (A)]		
Asphalt	Dry	70	75	79
	Wet	80	82	84
Concrete	Dry	73	78	82
	Wet	80	82	84

Source: (doctoral disertation)

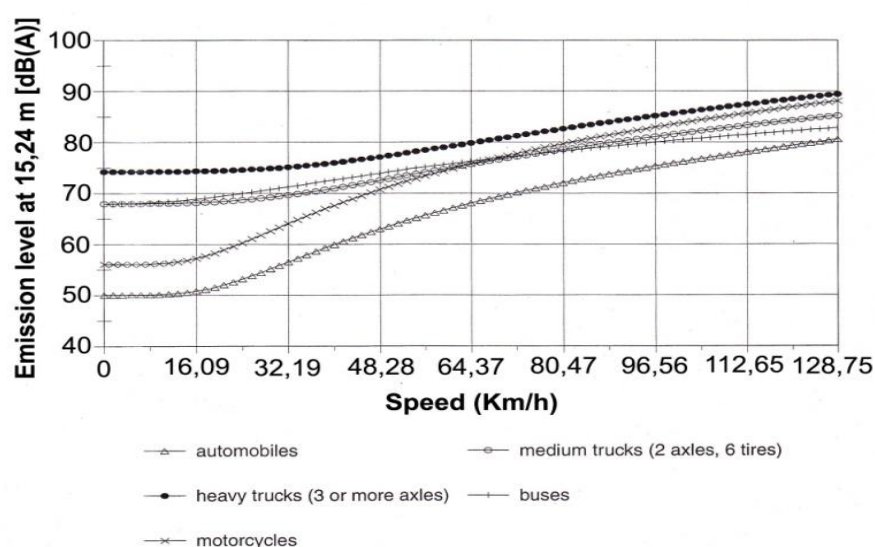
From Table 3, it can be seen that:

- the level of noise increases with increasing speed of movement and moisture on the road;
- pavement structures with wearing concrete layer are louder when the road is dry, while in wet condition on the wearing layer of the road, the advantage of asphalt pavements as quieter is lost;
- increasing the speed of driving, the condition of the driving surface as an impact on noise decreases.

2.1.2. Impact to transport noise from the speed of movement

It is important to note that at the movement of vehicles with low speed, engine noise is greater than the interaction between vehicles and driving surface. During the movement of vehicles with greater speed than 30 km/h for cars and 40 km/h for heavy vehicles, noise due to tire rolling down the road becomes significant, and at speeds exceeding 50 km/h becomes dominant. It can be concluded that on the roads where vehicles are traveling at high speeds - motorways (up to 130 km/h), the dominant noise is one that is created as an interaction between the wheels of the vehicle and the pavement surface, while the noise produced by the operation of motor vehicles becomes negligible.

Impact on noise has the type or category of vehicles, there for it is necessary to dispose the data bank not only about the size of traffic, but also about the category of vehicles that move along the specified road. Therefore, precise calculations are done when we divide the vehicles in several categories (Figure 7), not just two (light and heavy vehicles).

**Figure 7.** Emission level data as a function of speed for five vehicle types

Source: (Rochat J.L.: Transportation noise issue)

2.1.3. Impact of transport noise from tires

Noise caused by the tires depends on several factors including: the internal pressure in the tires, from the depressed area and the type of tread of the tire. High impact of tyres to noise, is evident in the fact that the worn tread of the tire due to greater land area, together with tyre pavement surface, is creating more noise. It should be noted that noise from the tyres is greater for trucks, while at cars it becomes dominant at high speeds.

By applying new technologies in the manufacture of automobile tires, and designing the type of tread of the tire, some brands in the manufacture of tires produced so called „Silent“ tires (Figure 8), that while interaction between tires and pavement surface for the same type of pavement surface and the same conditions on it, can produce significantly less noise.

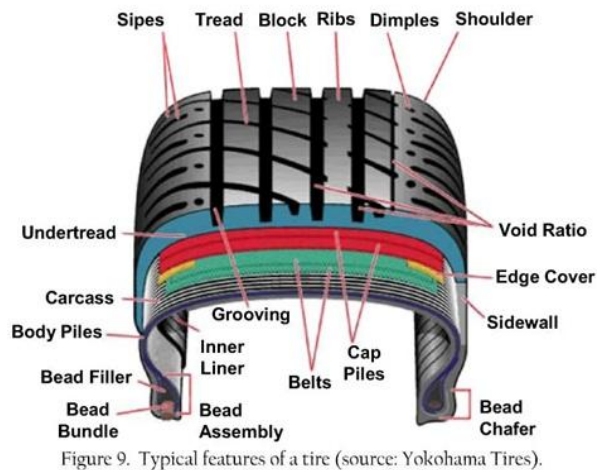


Figure 9. Typical features of a tire (source: Yokohama Tires).

Figure 8. Typical features of a tire

Source: (Yokohama tire catalogue)

Realizing the importance of the transport noise and performed tests defined by the Direction of European Commission (Direction EC 1222/2009 Source: European Commission's impact Assessment SEC (2008) 2860) the tires must have a label (Figure 9 and 10) which indicate the level of noise they produce expressed in decibels (dB). Marking the noise level of the tire is with black lines (Figure 11) as follows:

- 1 black line – very little noise from the tire;
- 2 black lines – average level of noise and
- 3 black lines – very noisy tire.

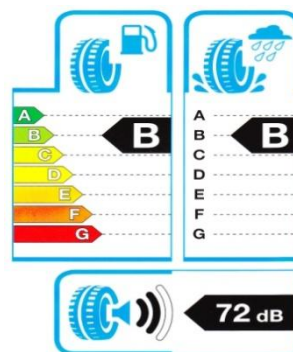


Figure 9 & 10. Label for tire noise according Direction EC 1222/2009

Source: (Michelin tire catalogue)



Figure 11. Marking the level of tire noise according Directive EC 1222/2009
Source: (Michelin tire catalogue)

3. THE PROTECTION MEASURES FROM ROAD TRAFFIC NOISE

Many of us everyday collide with the road traffic noise, although most affected are the people who live, work or attend school near a motorway or road with heavy traffic. Measures for protection against noise are divided into four groups (of which the first measure is the primary measure, while the remaining three are secondary measures) as follows:

- Measures to reduce noise at the source;
- Measures to reduce the spread of noise between the source and place of reception (This measure is applied in cases where it cannot be done to reduce the noise level at the source within the prescribed limits, and then it has to be done in one of two ways: the first intervention in place of emission by placing various types of barriers for protection from noise and the second is planning and managing the area near the road);
- Protection against noise at the site of emission (This type of measure is applied when you can't apply the previous two and includes the use of sound insulation and paying close attention to the design of buildings near the road) and
- Taking economic measures and adopting appropriate regulations.

The first measure to reduce noise at the source, or reducing the noise that occurs as an interaction between the tires of the vehicle and pavement surface and is performed by one of the following measures: Reducing the speed of movement, choosing the type of pavement surface, quality maintenance of roads and vehicles, etc.

The most common type of noise reduction on motorways is setting up a sound wall or sound barrier with wall shape, designed to reduce noise to 10 dB (A). These walls are built to lie longitudinal on the motorway blocking the visual path from the view of people who live along it. (Figure 12 & 13).

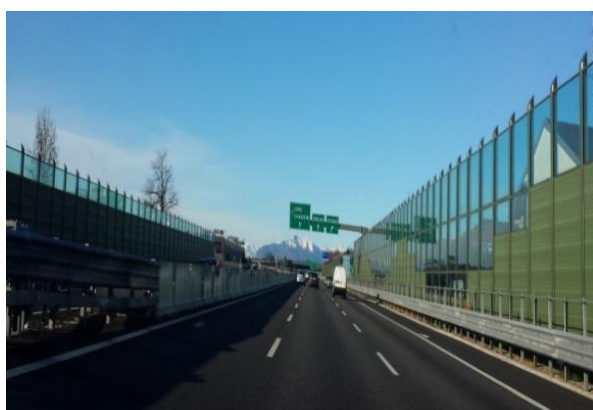


Figure 12 & 13. Acoustic barrier for protection against traffic noise (Switzerland)
Source: (own photo)

There are many different types of materials (they can be made of plastic, stone, wood, metal, glass and other) and structures to reduce the noise made by the available space, acceptance by the population and durability.

In order to be effective the barriers set along the roads, must satisfy several criteria including: a good ability to absorb sound, mechanical resistance and stability, resistance to frost and action of salt from winter road

maintenance, fire resistance, and to satisfy esthetic criteria to match its surroundings. There are two types of barriers: reflecting (they reject sound waves without reducing their intensity) and absorbing (they absorb part of the sound energy and emit a sound wave with reduced intensity). European experiences from the use of barriers for noise protection in urban areas, are shown on the following images (Figure 14 and 15).

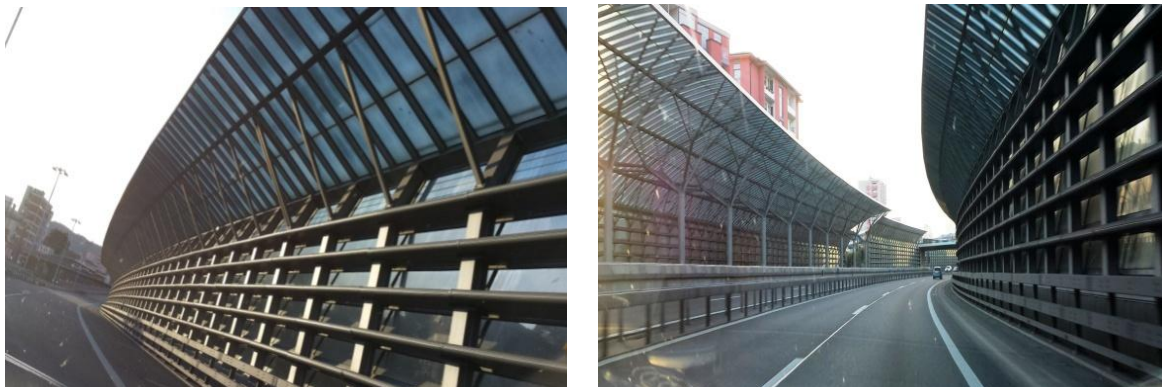


Figure 14 & 15. Acoustic barrier for protection against traffic noise in urban area (Switzerland)
Source: (own photo)

4. PROTECTION FROM NOISE ON MOTORWAYS AND URBAN STREETS IN THE REPUBLIC OF MACEDONIA

4.1. Protection from noise on motorways

It has been several years since an appropriate legal regulation to protect from noise was adopted in the Republic of Macedonia, although we are not yet a member of the EU. In the past protection from transport noise on roads in the Republic of Macedonia (motorways, national and regional roads), was not given a proper attention. The first protective walls – barrier were built during building a ring road around the city of Skopje (motorway A-2, E-75). Acoustic barriers were implemented, both absorbing and reflecting. Absorbing barriers are made of aluminum, perforated on one side, filled with mineral wool (Figure 16), while reflecting barriers are made of plastic and are transparent (Figure 17).



Figure 16 & 17. Absorptive and reflective acoustic barrier at Skopje Ring Road, motorway A-2 (E-75)
Source: (own photo)

4.1. Protection from noise on urban streets

Two authorized institutions in Republic of Macedonia are dealing with measurement of noise: the Ministry of Environment and Physical Planning (Central Laboratory of Environment) and the Ministry of Health (Republic Institute for Health Protection). In order to see the magnitude of noise in Skopje, traffic noise measurements were implemented by the Central Environmental Laboratory during April 2003 (Figure 18).

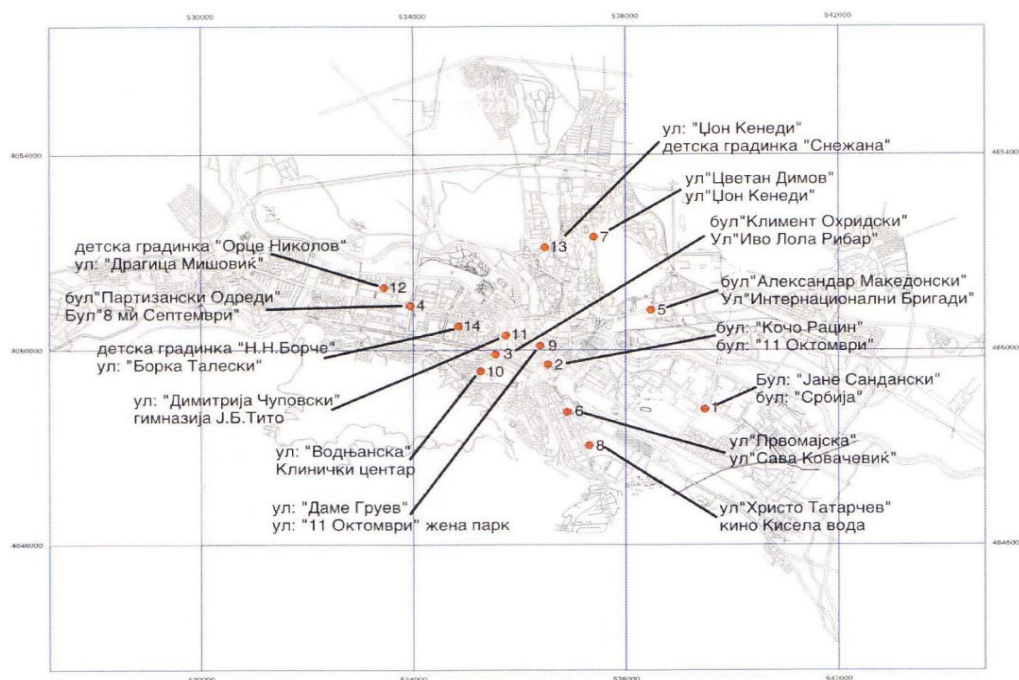


Figure 18. Locations of measuring points in the territory of Skopje
Source: (Ministry of Environment and Physical Planning)

The results of the measurements show that the measured noise level exceeds the maximum permitted level on all measuring points (Figure 19).

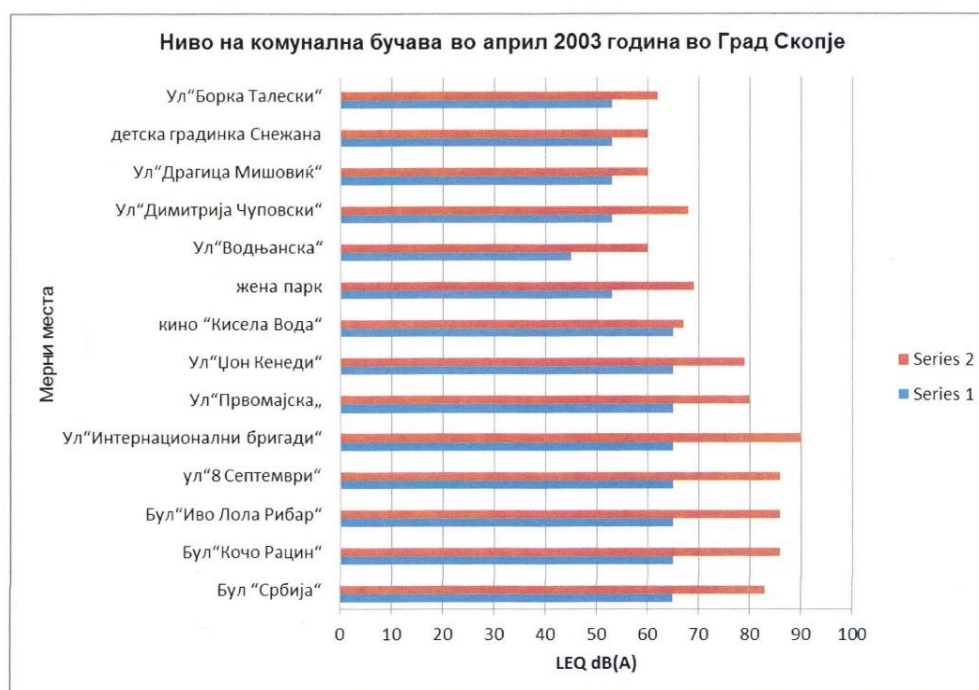


Figure 19. Results of measurements conducted by the Central Laboratory
Source: (Ministry of Environment and Physical Planning)

Despite the knowledge of the size of traffic noise and its impact, noise protection on urban roads in the Republic of Macedonia with protective sound barrier has been applied only in Skopje in two places: the transport center in the city center - reflecting barrier (Figure 20) and at exit / entrance from Skopje Djorche Petrov - an absorbent barrier during the construction of Ring Road of Skopje (Figure 21).



Figure 20. *Reflective acoustic barrier in Skopje*



Figure 21. *Absorptive acoustic barrier in Skopje*

Source: (own photo)

The reason for the lack of commitment to the protection against noise, probably lies in insufficient funding for road construction, and because there is no systematic monitoring of the noise on the road during exploitation. Other types of protection (applying the „Silent“ roads, etc.) have not been applied to the road network in Macedonia yet.

5. CONCLUSIONS

Despite the measures of traffic organization, lowering noise level can be achieved with proper selection, design and content of the pavement surface. Near the populated areas should be paid particular attention to eliminate bumps and provide a good connection between the final and lower layers of road construction and avoiding deformation of the parts of intense breaking and departure from the place. Dilatation joints of cement-concrete pavements needs to be performed so that it don't cause additional noise impacts.

One of the main factors to be considered in spatial arrangement, shall be noise pollution because it significantly affects the health of people.

The competent departments of roads, have to introduce the following activities in their practice:

- Planning and management of noise;
- Assessment of harmful effects on humans and the environment;
- Preparation of strategic noise maps and
- Preparation of action plans.

Implementation of these measures will result in better protection from transport noise.

References:

- [1] Directive 2002/49/EC of European Parliament and of the Council relating to the assessment and management of environmental noise (Official Journal of the European Communities, L189/12, 2002)
- [2] European Commission: Green Paper - Future Noise Policy, Brussels, 1996th
- [3] European Commission Working Group 5: Inventory of noise mitigation methods (Brussels, 2002)
- [4] Law on protection against noise in the environment (Official Journal of The Republic of Macedonia, No.79, Skopje, 2007)

- [5] Mijoski G. „Integral approach to the evaluation of attributes and indicators of pavement surface“, doctoral dissertation, 2010.
- [6] Rules for application of noise indicators, additional indicators of noise, method of measuring noise and methods of assessment indicators for noise in the environment (Official Journal of The Republic of Macedonia, No.107, Skopje, 2008)
- [7] Rochat JL: Transportation noise issue, Chapter 19 (Handbook of transportation engineering, USA 2004)
- [8] Rasmussen R., Bernhard R., Sandberg U., Mun E.: The little book of quieter pavements (U.S. Department of Transportation - Federal Highway Administration, Washington DC, USA, july 2007, p. 37)
- [9] Yokohama tire catalogue: AVS dB Decibel V550 - (2010)
- [10] Michelin tire catalogue (2012)
- [11] Watts GR: Traffic Noise Barriers (TRL Annual Review, 1995)
- [12] Lakusic S., Dragčević V., Rukavina T.: Mere za smanjenje buke od prometa u urbanim sredinama (2005)
- [13] Directive EC 1222/2009 Source: European Commission's impact Assessment SEC (2008)2860
- [14] Правилник за примена на индикаторите за бучава, дополнителни индикатори за бучава, начинот на мерење на бучава и методите за оценување со индикаторите за бучава во животната средина (Службен весник на РМ бр.107, Скопје, 29.08.2008)
- [15] Министерство за животна средина и просторно планирање, Централна лабораторија за животна средина, Кацарска И. „Мерење, анализа и контрола на сообраќајната бучава во урбани средини“ (2003 год.)