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RESEARCH ON THE EFFECTS OF PAVEMENT SURFACE CONDITION ON ROAD TRAFFIC NOISE

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ABSTRACT

The noise is meant by all unwanted sounds. As the years were passing by the noise has become more and more intense. European Union adopted Directive 2002/49/EC recognizing noise pollution problem. During the processes of planning and designing, and after the construction of new roads, it is of major importance to determine the level of traffic noise which is going to occur or which has already occurred. For that purposes mathematical models for prediction of noise emission and dispersion have been used. The aim of this paper is to represent the results of the research on the effects of pavement surface condition on road traffic noise. Research results were used to develop noise prediction models.

Key words: *noise, traffic road, road surface, pavement*

INTRODUCTION

The noise is meant by all unwanted sounds. Physically there is no difference between sound and noise. They differ in quantitative terms. When the sound loudness is above the prescribed limits, we call it noise.

Noise has always been important environmental issue for human beings. Noise produced by iron wheeled vehicles passing over cobbled streets in ancient Rome was significant and they introduced laws forbidding driving at night. In medieval Europe, it was banned to drive during the night hours, as the result of presence of noise produced by carriages. [1]

As the years were passing by the noise has become more and more intense. It is especially noticeable in urban areas. However, being aware of the growth of population along the interurban roads area, noise issue is no longer in city limits only. European Union adopted Directive 2002/49/EC recognizing noise pollution problem. According to the research by World Health Organization during 2000 more than 44% of the European Union population (about 210 million people) has been exposed to noise levels of above 55 dBaoccurred by road traffic and additional 7% (35 million of people) from railway traffic. Millions of people experienced health problems caused by noise presence. For example, about 57 million people suffer from nervousness caused by the effects of traffic noise. Healthcare analysis proved that about 245000 people in European Union suffer from cardiovascular disease caused by the influence of traffic noise. Rough estimates of external costs amount to about 40 billion Euros or about 0.4% of the European Union GDP. About 90% has been caused by the influence of passenger vehicles and trucks. [2]

Road traffic noise originates from internal-combustion engines, vehicle vibrations, air resistance overcoming and interaction between tires and the road surface.
Energy levels of noise emission depends on density and volumes of the traffic flow, vehicle speed, road geometric elements, type and condition of road surface, while noise dispersion depends on distance between the source of noise and the receptor, climatic and meteorological conditions, topographical conditions etc. [3]

During the processes of planning and designing, and after the construction of new roads, it is of major importance to determinethe level of traffic noise which is going to occur or which has already occurred. For that purposes mathematical models for noise prediction and dispersion are used. Determination of noise level varies from country to country. Many larger countries have developed their own noise prediction and dispersion models. Countries that do not posses their own models use models from other countriescalibratedfor local conditions or not. In Bosnia and Herzegovina, application of a German model is effective. This model does not take into account the condition of road surface. Therefore, it is of great importance to research this parameter too, as well as its incorporation into noise prediction models.

THE AIM OF THE RESEARCH

The aim of the research is to determine whether the road surface condition affects the road traffic noise emission and to what extent applying the methods of theoretical and experimental examination. Obtained results will be incorporated into the noise prediction model. Besides the road surface variable, other technical-exploitation and climatic-meteorological characteristics of two-lane roads have been collected and analyzed. In this way, a comparison of road surface condition effects with other parameters of two-lane roads will be made.

RESEARCH METHODOLOGY

For the purpose of this research, field data screeningswere conducted.

Research of parameters, namelya data screening, was conducted on highways, two-lane roads of Bosnia and Herzegovina. Sections or road junctions were selected by random sampling, obeying the principle of diversity and variability of the site per one variable at least. Data recording was carried out at 70 sites. The emphasis was on data collection within the large range of values per all variables. For example, in terms of speed, sections with an average speed from 40 to 90 km/h were represented, of longitudinal gradient from 0 to 7%, plains, hilly-mountainous regions, three seasons with temperature scope from -5 to 40 degrees, with lines and bends, some of them new, some reconstructed or significantly damaged, etc.Screeningswere performed on vital main road routes M5, M17 and M18 as well as on main roads with lower traffic loads. Research of parameters has been conductedduring the period of seven calendar months starting from January 2012, in order to capture all climatic and meteorological conditions.

Assessment of the pavement surface condition

Pavement surface condition method is based on PCR value calculation (Pavement condition rating). The resultis obtained by summarizing values of each type of pavement surface damage. The assumption is that each new pavement surface has 100 points. Aggregated value is deducted from the value of a new pavement surface.Based on that we get "PCR value" that represents numerical value of pavement surface condition [4].

$$PCR=100 - \sum_{i=1}^{n} T_i \,, \qquad (1)$$

where is:

PCR – numerical value for pavement surface condition
Ti – the value (points) for each type of damage

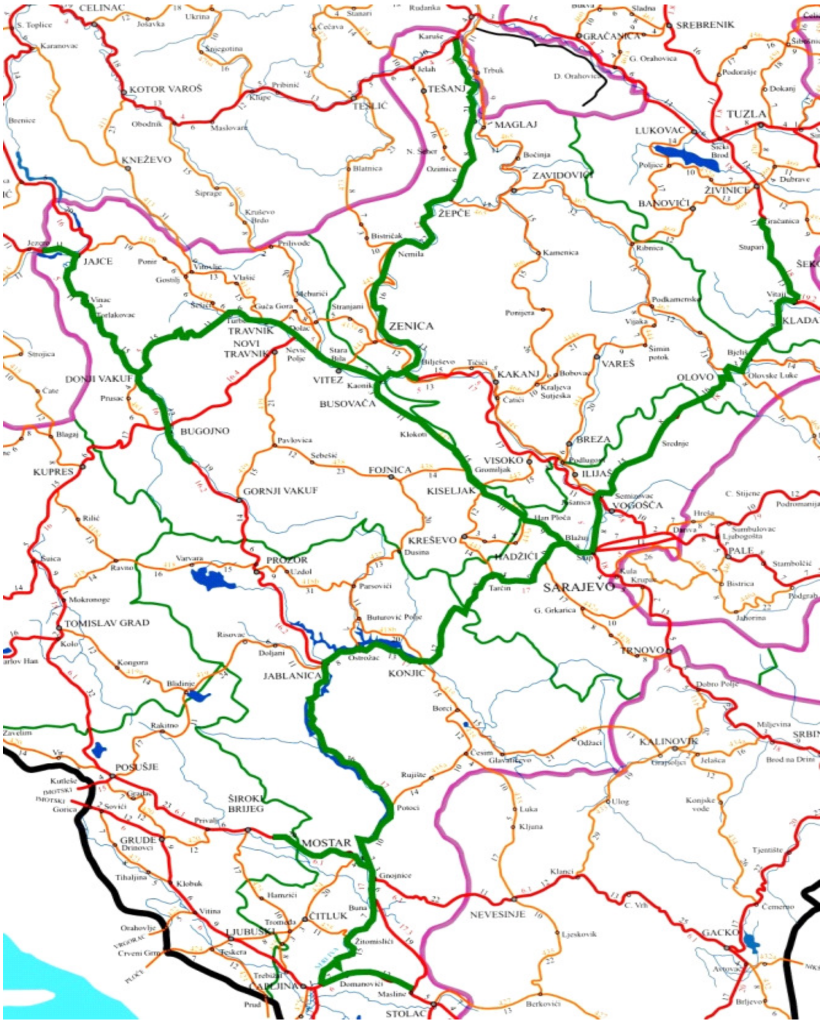

Figure 1 Research area

For each type of damage of road surface, two types of values have been defined as follows:

- by the intensity of phenomena,
- by the size of pavement surface covered with certain type of damage

According to the intensity ofpavement surface damage, values are classified (usually) into three groups:

- low-intensity (L),
- medium (moderate) intensity (M),
- high-intensity (H).

According to the scope and duration of pavement surface damage, values are classified into three groups as follows:

- occasional (O),
- frequent (F),
- permanent or extensive (E).

Table 1 Values (points) by the type of damage

Code of damage	Type of damage	Intensity			Scope		
		L	M	H	O	F	E
1.	Aggregate extraction	3	6	10	5	8	10
2.	Bitumen resurfacing	8	8	10	6	9	10
3.	Undulation	4	8	10	5	8	10
4.	Ruts	3	7	10	6	8	10
5.	Holes	4	7	10	5	8	10
6.	Patches	3	6	10	6	8	10
7.	Settlement	5	7	10	5	8	10
8.	Deformation of repaired holes and cracks	10	10	10	5	8	10
9.	Cracks at rut places	4	7	10	5	7	10
10.	Longitudinal crack	4	7	10	5	7	10
11.	Cracks at road margins	4	7	10	5	7	10
12.	Block cracks	4	7	10	5	7	10
13.	Other damages	4	7	10	5	7	10

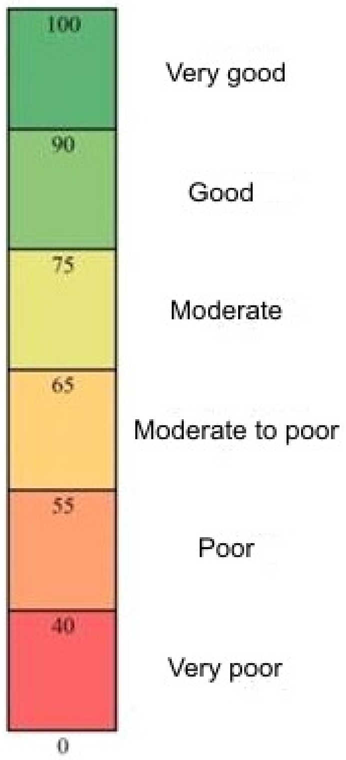

Figure 2 Scale of the road surface condition

Other parameters

For each surveying location, various distances were appliedbetween the source and the receptor (receiver) of measured sound pressure. The distance between the noise source and the noise receptor is considered to be the horizontal distance from the marginal carriageway line and vertical axes of sound level meter stand. Horizontal distance measurements for short distances were carried out usingcyclometer or GPS device.

Measuring of equivalent sound pressure level was conducted using sound level meter type SL-400, standard EN 61 672-1, class 2. Length of data recording for each location is one hour includingdata writing and storing in device memory. Number of recorded sound pressure levels per location is 3600.

Traffic load was recorded with video camera at each location. Recording lasts for 60 minutes. Based on video recordings, manual counting of traffic load and type of transport structure were performed.Traffic manual counting resulted in information on traffic volume at sections,it is to say the number of vehicles that pass the section within 60 minutes.Within the traffic load structure the following observed vehicle categories were defined:

- Motorcycles,
- Passenger vehicles,
- Passenger vehicles with trailer,
- Vans,
- Easy trucks (gross vehicle weight not exceeding 3.5 tons),
- Medium heavy trucks (gross vehicle weight from 3.5 to 12 tons),
- Heavy duty vehicles (gross vehicle weight exceeding 12 tons),
- Tractors and trucks with trailers and semi-trailers,
- Buses.

Average vehicle speed was estimated by determining the speed of object by analyzing video recordings. Namely, on the basis ofcertain video camera resolution, a recording of time when vehicle passes a certain part of road was made.

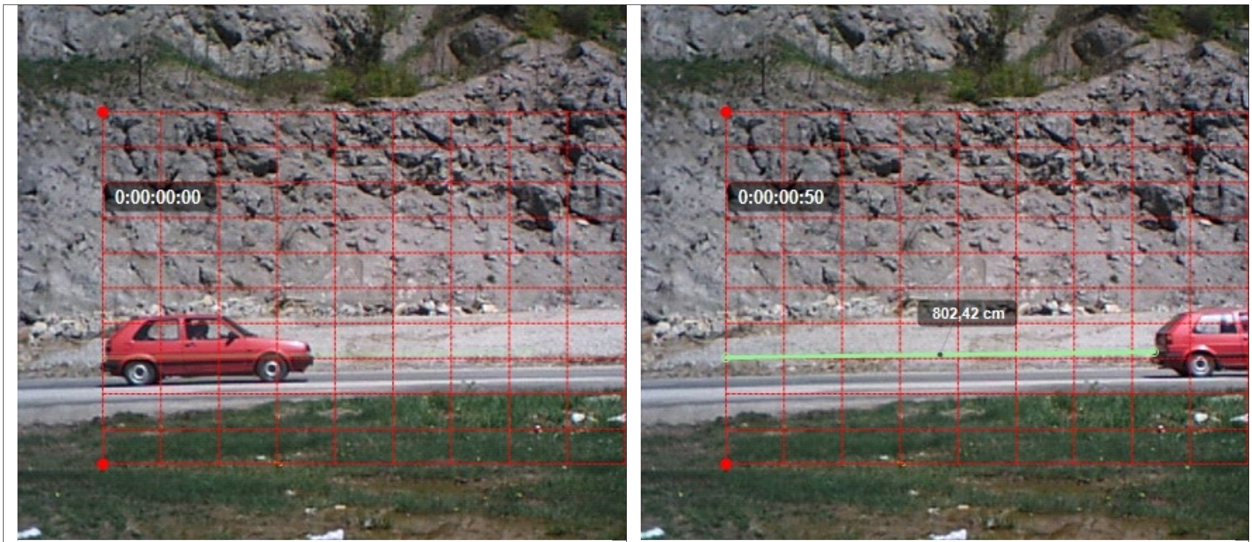

Figure 3 Determination of vehicle speed by measuring the distance traveled per unit of time

Method accuracy was tested in a way that the test vehicle of known speed passed along detection area, and the method was used to calculate the speed based on the video recording. Maximal test error amounted to 6 km/h. Having in mind that the speed is determined for all vehicles belonging to one category withinthe structure, followed by a calculation of the average, this result is considered acceptable. More significant error would be noticed with speed exceeding 100 km/h due to short vehicle passing time.

Geometric elements of the site, horizontal curve radiuses and deviation angles were determined based on GPS recording taken from the paper "Establishing of GIS – cadastral register of pavement constructions" [5]. For the purpose of that paper, a GPS recording of complete highway network in Federation of Bosnia and Herzegovina has been conducted. Using the test vehicle equipped with GPS device the whole network was recorded based on junction-section-junction method. Comparing the obtained value with previously known values from cadastral register of highway network, we get approximately the same values(difference between radiuses up to 5 meters, and horizontal curve 3-5 degrees), which can be considered satisfactory and the same method is applicable.

Longitudinal slope and the width of highway pavement at the shooting sites were taken from the "Cadastre register of highway network" [6, 7, 8].

Temperature of the pavement construction was measured with the laser thermometer. The measuring was performed by putting the thermometer one meter above the pavement surface every ten minutes during one hour. Average value was calculated using the obtained values of pavement surface temperature.

Humidity of pavement surface was determined and divided into three categories of state:

- Dry – pavement surface is free of absolutely any type of humidity,
- Wet – state of pavement surface humidity caused by the influence of frost and areas with no sun heat and with natural moisture,
- Humid – state of the surface immediately after rain or snow precipitation.

During the process of data recording any obstacle found in the area between the noise source (road) and receiver (sound level meter) thus preventing free flow of sound energy, was considered as a barrier. Firstly, it refers to the presence of bumpers, low-growing plants, walls up to 1,5 meters, snow mounds etc. Possible presence of barriers wasnoted at each research location.

Field conditions were divided into three categories of courts, namely:

- lowland,
- hilly and undulating,
- mountainous

After gathering field data a matrix of dependent variables (equivalent noise level) and arguments were formed with further application of statistical methods such as:

- The method of testing statistical significance of certain independent variables
- The method of regression analysis

Prior to the application of these methods, each of the independent variables was tested in terms of measures of central tendency, variability and flattening and asymmetry.

RESEARCH RESULTS

Based on field screening and statistical analysis, it is to say the testing of significance of some independent variablesat the significance threshold of 95%,the functional dependence between equivalent noise level as a dependent variable on one side and statistically significant variables as independent variables on the other side was established by applying multiple regression analysis. In addition to variable "PCR" Table 2 presents other variables that affect equivalent noise level.

Table 2 Results of the analysis of statistical significance of variables

Variable	Estimated parameters of the variables	P- empirical level of significance
Free term	45,75	0,0000
Barrier	-2,55	0,0001
Speed of heavy duty vehicles	0,12	0,0021
PCR	-0,035	0,0043
Pavement temperature	-0,07	0,0021
Percentage ofheavy duty vehicles	0,17	0,0035
log(distance)	-5,71	0,0000
sqrt(wind velocity)	0,77	0,0081
log (volumeof the vehicle)	4,46	0,0000

As it is obvious from Table 2, value of regression parameter with 'PCR' variable (which characterize the condition of pavement) is -0,035. The interpretation of this parameter is as follows: if the condition of pavement surface changes for 1 point (according to the methodology for assessment of pavement surface condition), it means that equivalent noise level has degraded by 0,035 dB. Therefore ifit is about new pavement surface immediately after its rehabilitation, assessed noise levelwill be reduced by 3,5 dB, Picture 4.

Having analyzed statistical significance of variable "PCR" it was determined that it had a value of empirical significance level of 0,0043. Since this value (at the significance threshold of 95%) is below 0,05(limit of confirming or rejecting the hypothesis on significance of individual variables), it influences observed phenomenon, or variation of this variable are involved into variations of equivalent noise level.

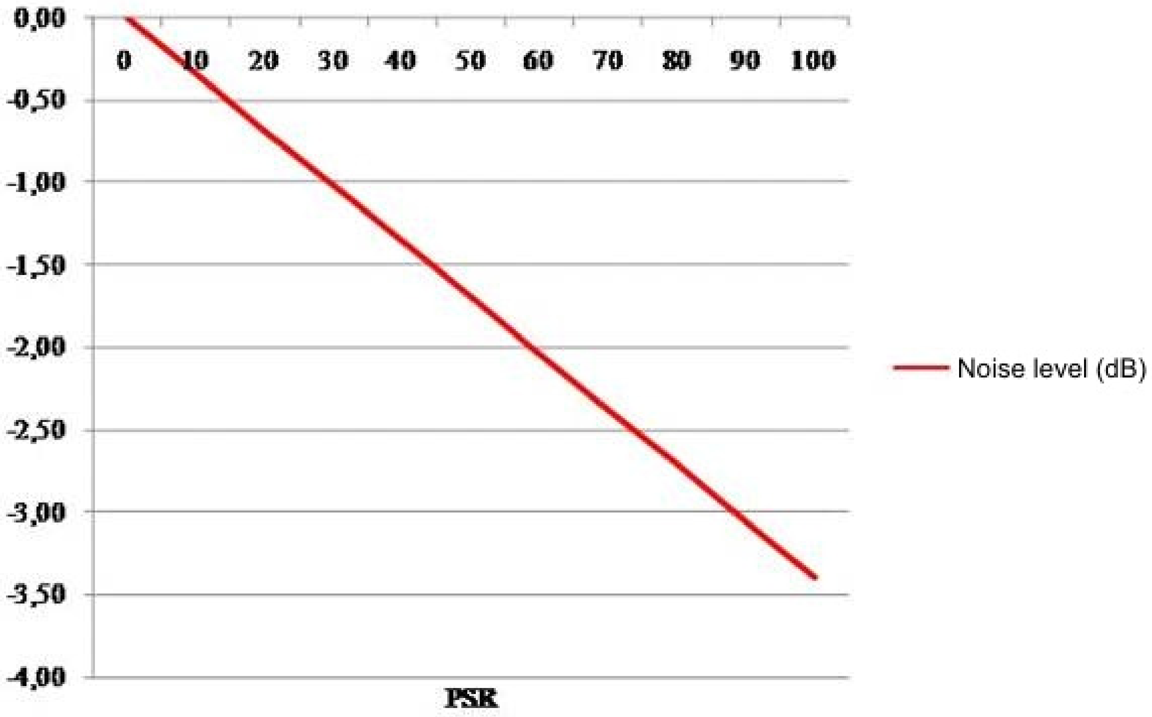

Figure 4. The reduction of noise level, depending on the state ofpavement surface

CONCLUSION

The respective research has proved that the condition of pavement surface affectsoccurrence of noise from road traffic wherebythe statistical analysis has also determined the percentage of its share in occurred noise level. Although the analysis was conducted forthe purpose ofdeveloping noise prediction model, facts derived from the paper can be used for making decisions related toreconstructions and rehabilitations of existing pavement constructions as a criteria for evaluation of the state of noise.

As recommendation for further research on pavement surface condition, it is necessary to direct the research towards introduction of other parameters such as the index of flatness, roughness, texture as well as variations in the terms of type and composition of asphalt mixture.

Although it has not been in our common practice yet, it is of major importance to introduce so-called "Low-noise" road surfaces, at least on high-density traffic roads.

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