



## NOISE PROTECTION OF ZAGREB ZOO FROM ROAD AND RAIL TRANSPORT

Stjepan Lakušić, Maja Ahac, Saša Ahac, Ivica Stančerić, Ivo Haladin

*University of Zagreb, Faculty of Civil Engineering, Department for Transportation*

### Abstract

Zagreb City Zoological Garden (Zoo) is situated within Maksimir Park, established by the end of the 18<sup>th</sup> and in the first half of the 19<sup>th</sup> century, on what then were the border areas of the city. Today, the Park is almost entirely surrounded by residential and business areas, and, immediately next to the Zoo, there is a road exceptionally burdened with road and tramway traffic. The problem of increased noise levels in public parks and other recreation and rest areas has not been given a major attention, until today. Increasing complaints by employees and visitors of the Zoo motivated the Management to start the procedure for improvement of the existing state with respect to noise protection. The elaboration of the study of noise protection walls, as optimum way of protection in urban areas, was entrusted to the Civil Engineering Faculty, University of Zagreb.

The paper presents a comprehensive procedure for implementation of the noise protection measures (measuring, calculation, protection) of the Zagreb Zoo. The measurements of the traffic noise levels were carried out within the Zoo grounds and on the outer side of its fence immediately next to the road. The measured levels of noise were used for verification of the acoustic calculation, elaboration of the noise propagation model, and production of noise maps for the existing noise levels. After the verification of the model, production of noise maps of the future state - with protection walls - was approached. During optimization of the position, length, height and type of the walls, the fact that the protected area is a monument of park architecture and a protected cultural good was taken into account as well as the fact that it represents an antique, but also a living part of the city for which it is necessary to keep and preserve its leading place among the historical sights, along with the application of the modern approach of protection.

*Keywords: road and tramway traffic noise, noise measurement, noise maps, noise protection walls*

### 1 Introduction

The Zagreb City Zoological Gardens (Zoo) were established in 1925 on Swan Island, in the middle of the first lake of Maksimir Park situated at what used to be the eastern edge of the city. On the opening day, the only animals that were in the Zoo were three foxes and three owls. Today, the Zoo extend on the surface of 7 ha (the surface of the land part is 5.5 ha), they comprise 275 animal species (2225 units) and employ 65 employees [1]. On the southern side of the Zoo, there is a major city four-lane bidirectional road Maksimirska cesta. It is intended for tramway and road traffic and it represents one of the major traffic links with the eastern and western parts of the city.



Figure 1 Ortophoto image of city with drawn location of Zoological Gardens

As the consequence of continuous increasing of the road and rail (tramway) traffic in the City of Zagreb, there have been more and more complaints by the employees about traffic induced noise levels in the Zoo. For the purpose of noise level reduction, the Zoo Management ordered the elaboration of the Project of the Zoo Fence from the Civil Engineering Faculty. The existing fence is in a very bad shape, so the first goal of this project is its complete replacement on the southern and eastern side of the Zoo and ensuring a safe, stable fence with minimum maintenance costs. The other goal is that the fence acts as a noise barrier, due to which the analysis of noise protection with the new fence was made within this Project. That analysis will be presented in this paper.

## 2 Noise Protection Project

### 2.1 Phases of elaboration of noise protection project

Elaboration of the Noise Protection Project of the Zoo consisted from several steps: acoustic calculation (measurements of the existing noise levels in the observed area, defining of traffic load on Maksimirska cesta as the main source of increased noise levels, elaboration of the noise propagation model for the existing state and elaboration of the noise propagation model after the executed protection for the purpose of its optimization) and elaboration of the Project.

### 2.2 Acoustic calculation

#### 2.2.1 Noise level measurements



Figure 2 Presentation of measuring points at location of Zoo

For the needs of the acoustic calculation, short-time 30-minute measurements of the noise level were carried out by Brüel & Kjær 2260, 2250 and 2270 sound level meters, under favourable meteorological conditions, at the height of 1.2m above the surface of the terrain, at 9 measurement points presented in Figure 2. There was a total of 35 measurements carried out during three daytime periods (morning, noon and afternoon) and one nighttime period. Concurrently with noise measurement, traffic surveying was carried out by hourly recording of the traffic load by a digital video camera set next to the measuring point 2, Figure 3.



Figure 3 Measuring noise levels and recording of the traffic load at MP2

### 2.2.2 Input data for acoustic calculation

The calculation of the noise levels caused by traffic from Maksimirska cesta was done by a specialized software LimA version 5.2, using the German RLS 90 method. In general, the necessary input data for the calculation by application of software is the complete terrain model of the area for which the calculation is done, and the known number of vehicles and the structure of the traffic flow.

For the needs of the calculation, on the basis of the topographic survey provided by the Zoo Management, a three-dimensional model of the Zoological Gardens' space was made. The data about heights of objects (animal shelters and office buildings), and the thickness and height of the existing plants (trees and the hedge) were defined by on-site observation and on the basis of orthophoto images.

By analyzing the video records of the traffic made during noise measurement, the traffic load of Maksimirska cesta was determined, whereby road vehicles were categorized in four groups: passenger cars (P), light trucks (LT), heavy transport vehicles (trucks and buses, HT), and tramways (T).

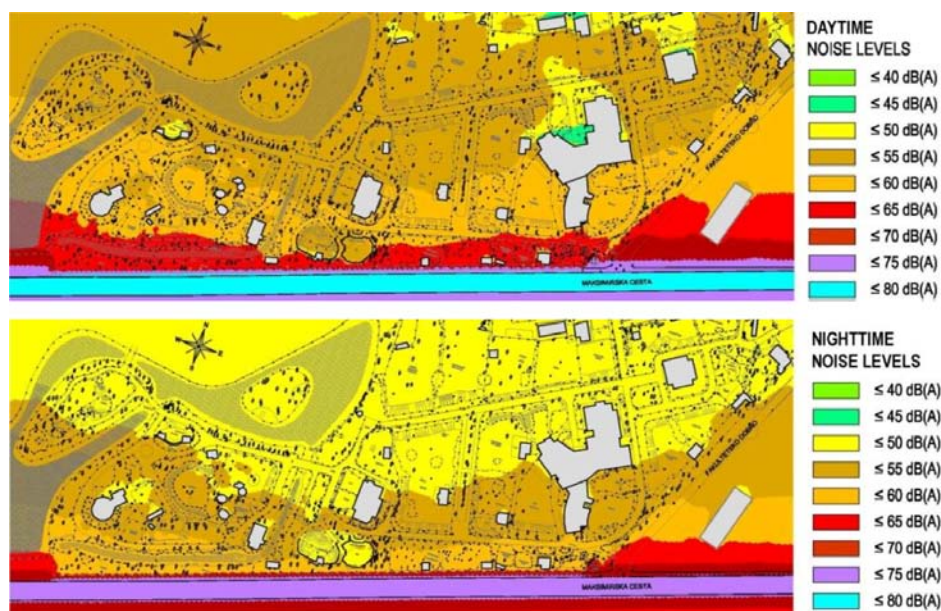
On the basis of the values presented in Table 1, it was concluded that the largest effect on the basic noise level on the observed location is made by traffic of tramways and passenger cars. The effect of tramways is particularly pronounced in the observed night period, since this is a tramway route leading to the depot in Dubrava at the eastern part of the city.

**Table 1** Structure of road and rail traffic in Maksimirska cesta

Lane	Time period	Day			Night
		08 <sup>00</sup> -09 <sup>00</sup>	11 <sup>30</sup> -12 <sup>30</sup>	16 <sup>00</sup> -17 <sup>00</sup>	23 <sup>00</sup> -24 <sup>00</sup>
	Vehicles type	Number of vehicles			
EAST-WEST	1 T	32	35	32	15
	2 P	1079	943	834	156
	LT	115	62	39	3
	HT	16	12	4	1
WEST-EAST	3 P	679	884	897	216
	LT	79	85	61	5
	HT	14	10	15	8
	4 T	39	36	32	43

### 2.2.3 Calculation of existing noise levels and model verification

On the basis of the mentioned input data, the calculation of the existing noise levels in the observed area in the daytime and nighttime period was made. Noise maps for the existing noise levels were made, in which noise zones were defined in classes of 5 dB(A) starting from 40 dB(A) to higher ones, Figure 4. For verification of the elaborated model, the calculated equivalent noise level values were compared with the values measured in the field, Table 2. The comparison showed that deviation of the mentioned values at the measurement points is satisfactory, i.e. that it does not exceed 3 dB(A), whereby the accuracy of the elaborated noise propagation model was confirmed. The results obtained by the model showed that the request of the Zoo Management for undertaking the noise protection measures was justified, i.e. that the existing noise levels within the Zoo exceed the values prescribed by the Regulation ( $L_{Aeq, day} \leq 65 \text{ dB(A)}$ ,  $L_{Aeq, night} \leq 50 \text{ dB(A)}$ ) [2].



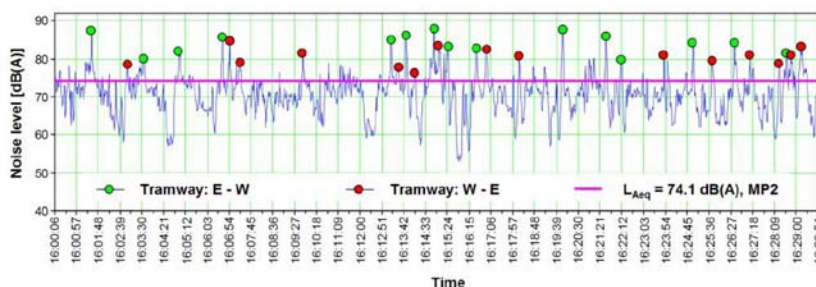
**Figure 4** Noise maps for day and nighttime period for the existing noise levels

**Table 2** Measured (M) and calculated (C) equivalent  $L_{Aeq}$  noise levels [dB(A)] at measuring points

MPn	Morning 07 <sup>30</sup> -09 <sup>30</sup>		Noon 12 <sup>00</sup> -14 <sup>00</sup>		Afternoon 16 <sup>00</sup> -18 <sup>00</sup>		Night 23 <sup>00</sup> -01 <sup>30</sup>	
	M	C	M	C	M	C	M	C
MP1	-	65.16	63.5	64.63	-	63.83	-	60.87
MP2	75.2	74.86	73.8	74.28	74.1	73.46	72.5	70.27
MP3	76.9	75.43	77.3	74.83	76.9	74.02	72.6	70.85
MP4	76.9	75.49	77.2	74.88	74.7	74.07	72.9	70.88
MP5	62.2	62.46	60.3	61.95	58.4	61.17	57.4	58.34
MP6	59.1	59.74	58.6	59.27	58.9	58.51	55.4	55.78
MP7	53.6	54.14	53.4	53.66	51.8	52.88	44	46.93
MP8	61.8	61.49	60.0	61.00	60.3	60.22	52.8	54.10
MP9	-	54.94	-	54.46	57.0	53.70	-	47.73

### 2.2.4 Selection of optimum noise protection measure

The detailed analysis of the results of measurement showed that the traffic of tramways represents the largest source of noise. The said can be illustrated by a time diagram of the noise level obtained by measuring in the period from 4:00 p.m. to 4:30 p.m. at the MP2 measurement point, Figure 5. It is evident that the maximum noise level values (peaks) are the result of traffic of tramways. Each passing of a tramway raises the noise level by 8 to 10 dB(A). The effect of peaks in the presented diagram affects the equivalent noise level as well. The performed analysis in which the mentioned peaks were exempted produced a reduction of the equivalent noise level by as much as 2.5 dB(A).



**Figure 5** Effect of tramway vehicles on noise level (afternoon period, MP2)

One of the most efficient measures of protection from increased noise levels is reduction of noise at the source. In case of the Zoo, as a public purpose park area, situated along the road with a very high traffic load, the application of the measure of “noise level reduction at the source” by reducing the speed of vehicles would be not only unpopular, but it would be difficult to control. Also, execution of works on modification of the track superstructure, whereby emission of rolling noise would be reduced, can hardly be expected at the moment. Because of that, from the viewpoint of efficiency and cost-effectiveness, construction of walls for noise protection arose as the optimum measure for reduction of traffic noise levels. Experience in application of this kind of protection on roads outside of settlement areas proved that, immediately upon construction of a highly-absorbent wall with the sufficient length and height, noise reduction by as much as 15 dB(A) can be achieved in the protected area. If protected structures are in the immediate vicinity of a road with a heavy traffic load, the reduction of noise level variate from about 5 to 10 dB(A) [3]. Since an urban environment is

in question here, and also one of the monuments of park architecture of great importance, and a favourite citizens' place for recreation and rest, the problem of wall dimensioning was approached with special care.

### 2.2.5 Simulation of noise levels with noise protection walls

The height and the length of the noise protection walls was obtained by the optimization carried out by application of the specialized software (LimA). The input parameters of the calculation were the maximum height of the walls of 4m above the terrain surface, and reduction of noise within the Zoo to the levels defined by the Regulation. The calculation showed that the execution of the noise protection wall with the height of 3.5m (along Maksimirska cesta with the length of 377.5m, and along the so-called Fakultetsko dobro, the land owned by the Faculty of Agriculture, with the length of 60m), can reduce the existing noise levels at the targeted places of emission inside the Zoo to values prescribed by the Regulation. These areas are the animal shelters next to the fence and paths on which movement of visitors is allowed.

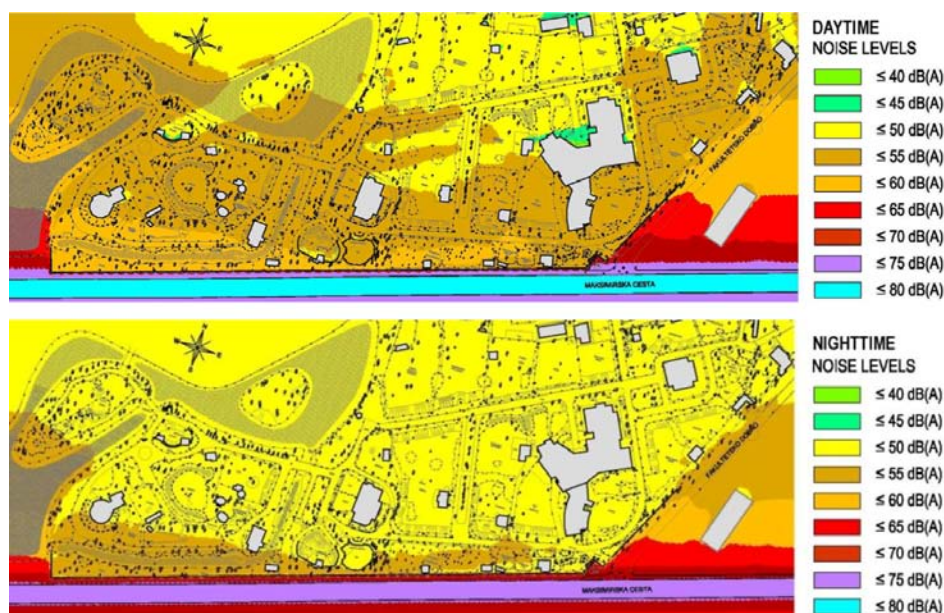


Figure 6 Noise maps for day and nighttime period with noise protection wall

### 2.3 Elaboration of the Project – defining the structure of noise protection wall

The Zoo Management made the following requests that should be met by the new fence: possibility of construction by light machinery and fast construction so that traffic on Maksimirska cesta and daily work activities of the Zoo personnel would be disturbed as little as possible, sufficient mechanical stability and resistance of the structure, good protection from traffic noise from Maksimirska cesta, architectural design that would integrate best into the area and minimum expenses of construction and maintenance of the fence.

In order to meet the requests for the fastest possible construction with minimum disturbance of daily activities, the design anticipated that the new fence be executed by the assembly or semi-assembly way of building. As the fence material, absorbing concrete was selected. For the fence construction, other materials can be applied too, such as wood, aluminum or

polycarbonates, but it was concluded that the application of concrete ensures the above requests best, particularly the request of simple maintenance.

On the basis of the data obtained by the acoustic calculation about the necessary height, length and type of the noise protection wall, and after selection of the wall materials, the calculation of its mechanical resistance and stability was made (for wind speed of 22m/s). The form and the type of pad foundations were selected so as to avoid their interference into the sidewalk profile in Maksimirska cesta, and to preserve the hedge between the sidewalk and the existing fence. During laying of the wall line in the layout, it was endeavoured to have the longitudinal axis of the future wall follow the line of the existing fence. Since an intervention within the space of the protected monument of park architecture is in question here, care was taken that the foundations set in the mutual distance of 4m do not endanger the trees within the Zoo. After mounting of the foundations, prefabricated concrete one-side absorbing panels are inserted between prefabricated reinforced concrete posts mounted over a mandrel into the foundation joint. Also, architectural designing of the front and the back side of absorbing panels is anticipated. One of the proposals for appearance of the front side of the panels and visualization of the final appearance of the wall from Maksimirska cesta can be seen in Figure 7.



Figure 7 Visualization of future appearance of barrier

### 3 Conclusion

Experience acquired during elaboration of this project completely confirmed the fact that protection from traffic noise in urban environments is a very complex problem, particularly when construction of noise protection barriers is in question. In general, lack of space for placing the barrier is a big problem in such locations, and the need for its architectural design for the purpose of the best possible integration into the surroundings. Therefore, while designing, care was taken that the barriers ensure the necessary noise protection of employees, visitors and inhabitants of the Zoo by their dimensions and design, but also that they make an interesting, recognizable and esthetically acceptable addition to the vistas of Maksimir Park, Maksimirska cesta and the very Gardens.

### References

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