Toward noise protection planning in urban areas

V. Dragcevic, S. Lakusic & T. Rukavina
University of Zagreb, Faculty of Civil Engineering, Croatia

Abstract

Planning noise protection measures differs in the case of construction of new roads or the reconstruction of the existing ones from the implementation of protection measures in the zones of existing roads where conditions have deteriorated due to increase in traffic load. In the zones of existing roads the possibilities of applying protection measures are very different due to both spatial limitations and very different vehicle structure and traffic flow characteristics. The research shown in this paper is based on three characteristic examples in Zagreb. The possibilities of applying different protection measures and their combinations are considered with the aim to reduce environmental noise. The paper describes two typical locations beside the existing roads, one in the narrower and one in the wider city centre, on which noise level and traffic load were measured. The third location considered in the paper is the important city traffic junction, which was significantly reconstructed. The results of conducted measurements were analyzed and the possibilities of applying noise mitigation measures in urban centres were considered.
Keywords: road traffic noise, urban area, noise protection, urban planning.

1 Introduction

It is a fact that road traffic noise, despite the technological improvements regarding all influential parameters such as the vehicles, the road surface and traffic regulation, in urban areas has seen no improvement of the conditions concerning a decrease in the noise level. According to the data of the European Commission the peak values in urban areas are, in general, not increased, while the period of the exposure to increased noise levels is prolonged [1]. It is caused by the change in the way of life. The residents not only travel to work and back, but also engage in sports and cultural activities. Due to specific features of a particular area the improvement of the situation, within the urban environment, is

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not an easy and unequivocal task. It is necessary to pay special attention to the structure of newly erected buildings, and, depending on the content and purpose, to locate them on the basis of measurements and calculations. With the aim of fulfilling the criteria prescribed by the regulations it is necessary to implement adequate protection measures which significantly depend on the characteristics of the protected area. As a result of general globalization in all areas, and thus in the area of planning and development of the urban environment, the ways of people's and goods' movement in it and, in general, the way of life of the people who live in such areas, from the point of view of the noise it can be said that regardless of the part of the world we are in, the basic ideas in studying and solving the noise issue are very similar. In that sense the experience shown in this work on three concrete examples can certainly represent help in planning and implementation of the noise protection measures even in other urban areas regardless of where in the world they are located.

2 The aim of the research

The noise level measurements in the Republic of Croatia started in the seventies in Zagreb. The results at that time showed that noise in all parts of the town was over 70 dB(A), and maximum values ranged even to 85 dB(A), [2]. The measurements carried out recently show that there was no decrease in the noise level but the conditions in some areas additionally deteriorated. Wishing to change the situation, and in accordance with the European points of reference, important steps have been made in that direction. In 2003 the Noise Protection Act [3] was proclaimed which is completely harmonized with the Directive 2002/9/EC [4] and with the legislation of the European Union. The highest allowed noise levels in the environment where people live and reside are prescribed by the Regulation [5]. Counties and towns, in accordance with the Law, within their urban development plan pay greater attention to this segment of environmental protection.

Recently there have been more frequent complaints of the citizens to town administrations regarding the increased levels of traffic noise who live on the locations situated near the main city roads. Since the authors are best acquainted with the situation in the city of Zagreb, this paper describes the measures and their effects aiming at the improvement of the concrete locations in Zagreb.

In order to point at the importance of the solution The Faculty of Civil Engineering of the University of Zagreb started a project which aim is to determine the noise situation in the environment, as well as the proposition of protection measures and further activities regarding the improvement of the conditions in the areas exposed to higher noise levels than allowed. A part of the research will be carried out within this year-approved project co-financed by the Ministry of Science, Education and Sport. The project should be realized in two basic phases. The first phase, which is in course, is the making of the pilot project which includes: the determination of noise situation – making noise maps for particular locations, the proposition of possible protection measures and the plan of further research. The second phase would comprise: making a noise map for a greater number of locations in the city of Zagreb, defining priority locations for the implementation of the protection and analyzing and proposing protection measures for the observed locations. The results of the second phase could represent the starting point for making the road traffic noise protection strategy on the level of the city of Zagreb. The basic document for the city of Zagreb, the general urban plan (GUP) [6] was passed in the same year as the Law [3]. It prescribed the implementation of the provisions of the Law and the appropriate regulations, making of noise immission maps and the monitoring of implemented measures. It defines the purpose of the areas and prescribes all activities that should be carried out in the city, starting from the construction all the way to environmental protection. For special purpose areas the maximum allowed noise levels are prescribed for the day and night period, while for the evening period, as in the Regulation [5], the same values as for the day period are applied. Table 1 shows valid values for the zones observed in this paper according to [5, 6].

Table 1: Maximum allowed noise levels in dB(A).

<table>
<tr><th rowspan="2"></th><th colspan="2">GUP of city of Zagreb, [6]</th><th colspan="2">Regulation, [5]</th></tr>
<tr><th>Day</th><th>Night</th><th>Day</th><th>Night</th></tr>
<tr><td>Location A (wider city centre)</td><td>55</td><td>45</td><td rowspan="3">65</td><td rowspan="3">50</td></tr>
<tr><td>Location B (narrower city centre)</td><td>60</td><td>50</td></tr>
<tr><td>Location C (edge of the narrower city centre)</td><td>65</td><td>50</td></tr>
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3 The first phase of research

The measurements were carried out on 15 locations in the areas of different purpose along the roads with high traffic volume. The measurements were partly carried out on the locations where citizens' complaints were directed to city authorities, and partly on those chosen by the team involved in this project. 24-hour measurements were carried out on three locations, while on others there were short-term measurements in the period day, evening and night. It turned out that the highest noise levels in the day period were in the morning and afternoon, during leaving for work or coming back, while the noise levels at 22^{00}, when the period night starts were still of the same intensity as in the day period and later start and end of the day and evening period would be more appropriate for real conditions. It can generally be said that noise levels on particular locations are significantly higher than allowed values, so the situation is alarming and requires the implementation of protection measures as soon as possible.

3.1 The description of the locations and the criteria of research

Due to the limited space the illustration within this paper includes three relevant locations, fig 1: Location A (Cvjetno settlement) – Slavonian Avenue, Location B (Klaic Street) – a part of "green wave" in the direction east-west and Location C (Branimir - Drzic Intersection) – southern edge of the narrower part of the city.

Location A: Slavonian Avenue, fig.1, two-way city highway with two traffic lines for each direction, is one of the most important roads, which connects the west and the east part of the town. Except the city traffic, the transit cargo-traffic also runs on this road. In the close proximity there is settlement with 7 to 10 stories residential buildings.

Location B: Klaic Street, location B, fig. 1, is one of the three city's most important roads, which faithfully presents the real situation in this part of the city. The facilities situated here are educational institutions, hospital, as well as residential buildings (mostly four and five-storey buildings). On this location, within the reconstruction in 2003, the new road surface structure was made and the traffic regulation was changed. In addition to the analysis of the situation the influence of the reconstruction on the noise level has also been analysed.

Location C: Branimir – Drzic Intersection, fig.1 has an important role in connecting western and eastern part of the city. Due to the non-built eastern part of this intersection almost all the traffic in that direction went along the roads of lower rank, through residential areas, traffic jams and congestions thus being a frequent occurrence. In the close proximity of the intersection and the road that was built in 2005 there are residential buildings up to 12 m high and the business ones of the same height or lower. On this example a model of the environmental noise situation assessment by means of modern methods and the use of specialized software have been presented. The verification of reliability has been carried out for the applied model by means of environmental noise situation assessment before and after the reconstruction by field measurements.

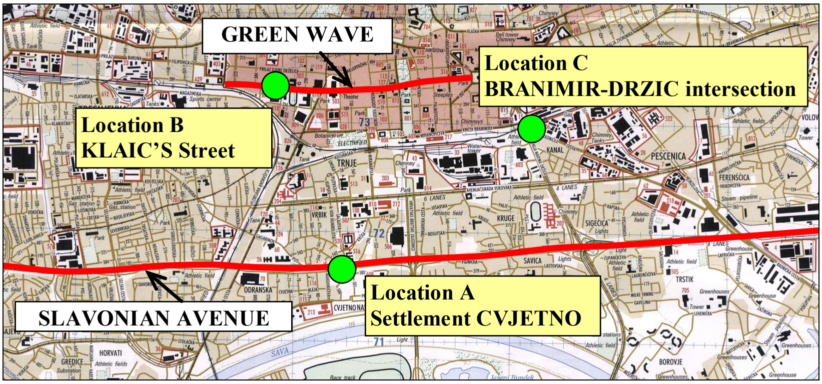

Figure 1: The illustration of the tested locations.

3.2 Traffic measurement

Traffic measurement was carried out on 60-minute video recordings. On Locations A and B the measurement was carried out for the day and night period, fig. 2. In the evening period the traffic was not measured since the measurements showed that noise levels on both locations in the evening period do not significantly differ from those in the day period. The traffic measurement on

Location C was performed only in the morning period of day. The vehicles were divided into two basic groups: road and rail vehicles. Road vehicles were divided into the following categories: passenger cars, light and heavy freight vehicles and motorcycles. Trams operate only on Location C.

Traffic measurements on Location A, fig. 2, showed that in the day period the traffic volume was extremely heavy. The share of freight vehicles in the traffic flow is less than 6% in the day period, since in the night period is less than 1%. Consequently, passenger cars have the biggest influence on the noise level during the whole day. The data on traffic measurement on Location B before the reconstruction were obtained from the Zagreb City Office. During the reconstruction cycling tracks were built and parking fee was introduced in the whole street. Fig. 2 shows the results of traffic measurements after the reconstruction. It turned out that there is almost no change in the traffic volume compared to the situation before the reconstruction.

The existing three-leg intersection, Location C, was turned into a four-leg one in the course of reconstruction. The construction of the new leg of the intersection in east direction caused the change in the traffic regulation, which refers to road motor traffic and pedestrian traffic, fig. 3.

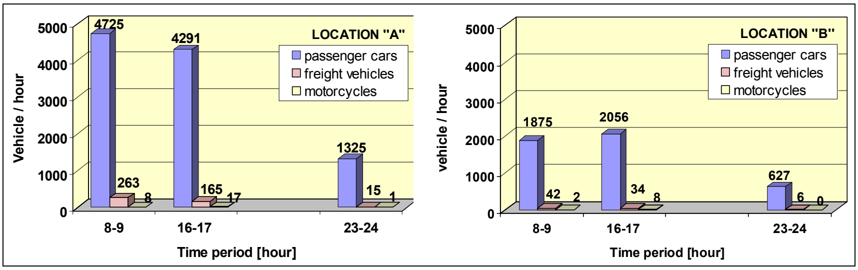

Figure 2: The illustration of traffic volume on Locations A and B.

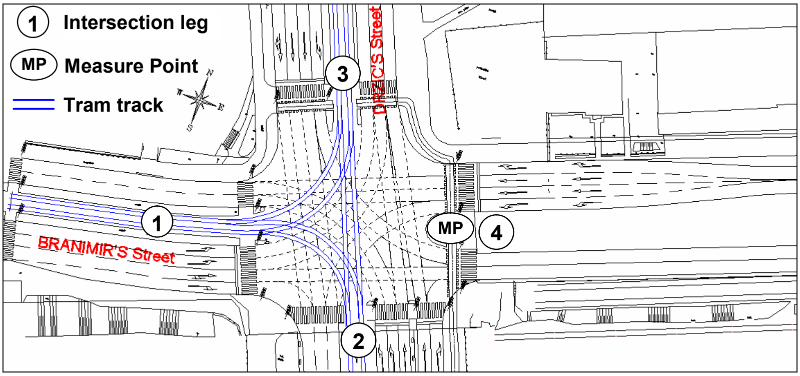

Figure 3: Branimir - Drziceva Intersection after the reconstruction.

Additional moving directions for road vehicles were introduced and the number of lanes for some existing directions was changed. There were no changes in traffic regulation referring to tram traffic. Traffic measurement and the survey of the number of vehicles according to the group and category depending on the moving direction was carried out by the same measuring equipment and under the same conditions for the situation before and after the reconstruction.

3.3 Noise level measurement

Noise level measurements were conducted on working days by precise sound meters with convenient weather conditions at the height of 1.2 m. On the basis of the whole-day measurement [7], time periods within the day (day, evening and night) were chosen, taking into consideration the most inconvenient periods concerning the noise level, and short-term measurements were carried out.
Location A: Conducted measurements showed that equivalent noise levels L_{eq} in the period day, evening and night, table 2, were higher than allowed (see table 1).

Table 2: Noise level (average) on Location A in dB(A).

Day (6^{00} to 20^{00})						Evening (20^{00}- 22^{00})			Night (22^{00} to 6^{00})		
Morning 8^{00} to 9^{00}			Afternoon 16^{00} to 17^{00}			21^{00} to 22^{00}			23^{00} to 24^{00}		
L_{10}	L_{90}	L_{eq}	L_{10}	L_{90}	L_{eq}	L_{10}	L_{90}	L_{eq}	L_{10}	L_{90}	L_{eq}
74.23	67.37	71.60	74.10	67.05	71.57	72.53	63.00	69.50	70.83	58.97	67.67

The basic noise level in the environment L_{90} is extremely high which shows the continuously heavy traffic load. Parameter L_{10} shows that the temporary increases in the level of noise significant during the whole day are higher than 75 dB(A). On time diagrams it is noticed that noise levels in the day and night do not fall below 60 dB(A), and in the night period below 55 dB(A). From 24^{00} to 4^{30} noise levels fall to 45 dB(A) after which they gradually increase and at 6^{00} they correspond to the values of the day period. Maximum noise level values are generated by the freight vehicle traffic and partly are the consequence of the acceleration or the traffic of badly maintained passenger cars. It is usual that the heavy vehicles traffic is very “dense” in the period from 8^{00} to 17^{00}. The maximum values of the noise level in the day period often rise to 80 dB(A) and occasionally to 90 dB(A). In the evening period more significant difference is not noticed compared to parts of the day period, namely the one from 6^{00} to 8^{00}, and 18^{00} to 20^{00}. In the night period the maximum noise levels from 22^{00} to 24^{00} are mainly lower than 80 dB(A) while from 24^{00} to 4^{30} they are mainly below 80 dB(A). In the period from 4^{30} to 6^{00} maximum values are increased to 80 dB(A).
Location B: Noise level measurement was carried out before and after the reconstruction on four measurement places (MP), fig. 4, and the results are shown in Table 3.

In both cases the equivalent noise levels are higher than allowed, table 1, especially in the night period. In the day period the traffic flow is instable with low speed, frequent stoppages and reduced possibilities of manoeuvre. In the evening period longer periods with noise levels lower than 50 dB(A) can be noticed, i.e. with the green light on the traffic lights the vehicles do not pass although but when vehicles pass the levels are mostly up to 70 dB(A). At night, phases of low noise levels from 45 dB(A) to 50 dB(A) are longer.

Table 3: Noise level before and after the reconstruction (average).

Results of noise level	Day: 6^{00}-20^{00}						Evening: 20^{00}-22^{00}			Night: 22^{00}-6^{00}		
	Morning 8^{00} - 9^{00}			Afternoon 16^{00} - 17^{00}			21^{00} - 22^{00}			23^{00} - 24^{00}		
	L_{10}	L_{90}	L_{eq}	L_{10}	L_{90}	L_{eq}	L_{10}	L_{90}	L_{eq}	L_{10}	L_{90}	L_{eq}
Before reconstr.	**71.0**	**59.2**	**67.9**	**71.6**	**59.2**	**68.4**	**70.3**	**51.1**	**66.5**	**68.5**	**47.4**	**64.0**
After reconstr.	**70.5**	**56.8**	**67.5**	**70.7**	**56.2**	**67.5**	**69.3**	**51.6**	**65.5**	**68.5**	**48.6**	**64.7**

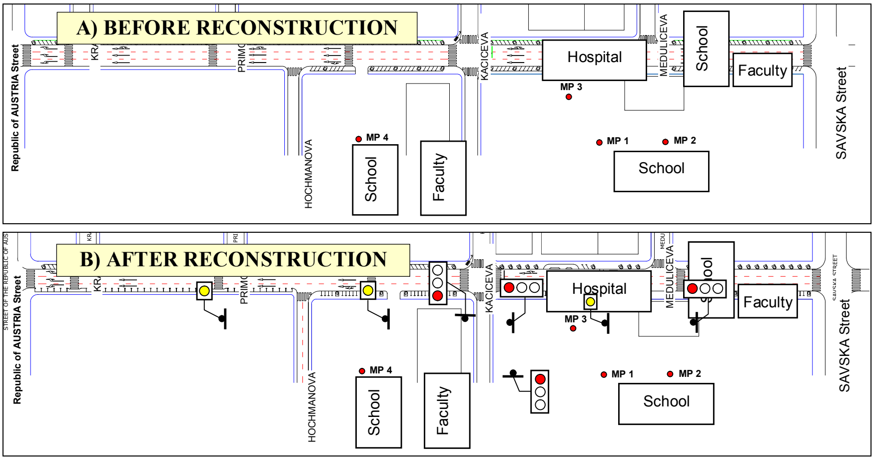

Figure 4: Klaic Street: a) before reconstruction; b) after reconstruction.

It is generally visible that the basic environmental noise level L_{90} is considerably lower in the evening or night period than in the day period, which shows a significant decrease in the traffic load compared to the day period. Parameter L_{10} shows that the temporary increase in the noise level does not vary that much as L_{90}. This is so because of the fact that the lower intensity of the traffic the higher the speed, often higher than allowed. L_{90} for periods evening and night does not significantly differ compared to the situation before the reconstruction while it is lower for the day period. This is not a result of the increase in the number of vehicles but of the higher speed at night (on newly reconstructed carriage-way) as soon as the traffic flow conditions allow that. The equivalent noise level in the night and evening period compared to the situation before the reconstruction was reduced by 1 dB. In the night period the noise level increased by 0.7 dB(A). It was caused by the increase in the vehicle speed, which in periods of low traffic density drive faster if they "catch" the phase of the green light on the traffic lights and do not slow down due to uneven areas and damaged carriage-way as before the reconstruction.

Location C: The mean value of the measured equivalent noise levels L_{eq} on measurement place, fig. 3., was 68.9 dB(A). By using the computer programme LIMA version 4.2 [8], by the German computation method RLS 90 [9], environmental noise situation was simulated at the height of 1.2 m, fig. 5. The applied computation model is: the immission position is in the middle of the lane, each lane is observed separately, traffic volume (the number of vehicles per hour) depending on the movement direction is equally distributed along the lanes. For calculation reasons, it was supposed that the vehicles move uniformly, so the average movement speed of personal and freight vehicles as well as trams was set. The position of traffic lights was taken into consideration and the absorption of green areas was neglected. The equivalent noise level determined by the presented model by computer simulation on measurement place which corresponds to the position of the measuring device in the field was 73.5 dB(A). The experts who deal with these issues think that the departures of the model with regard to field measurements up to 3 dB(A) can be considered satisfactory. In this example the difference is 4.6 dB(A). Short-term noise level field measurements show oscillations up to 1.6 dB(A), and due to impossibility of finding better position, the measuring device was placed on the traffic island planted with bushes which were almost up to the microphone height. That was not taken into consideration in the calculation, but it to a certain extent contributed to the difference between the noise level measured in the field and the noise level obtained by computation model.

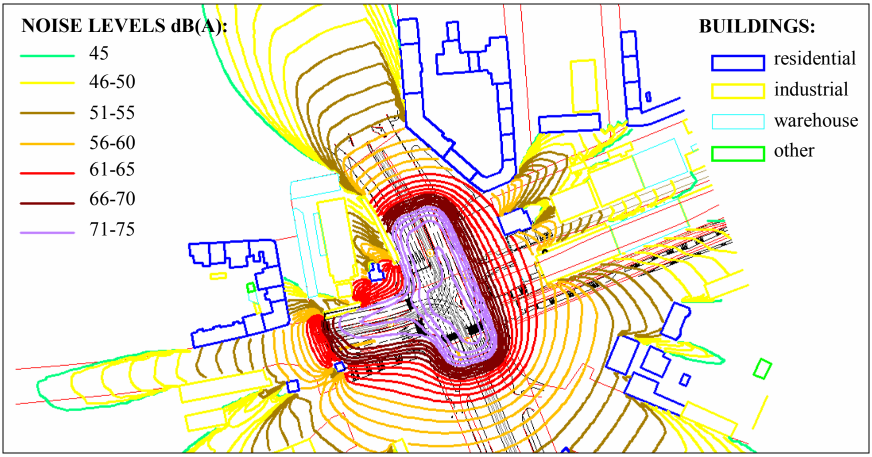

Figure 5: Noise map at the height of 1.2 m before reconstruction.

Traffic and noise level measurement after the reconstruction with the same measuring equipment and under the same conditions gave the mean value of the equivalent noise level of 72.8 dB(A). The sound meter was positioned on the new traffic island and there was no vegetation in its surroundings. The environmental noise situation on the newly reconstructed and built intersection was simulated by the same computation model, and the equivalent noise level on the measurement place that corresponds to the position of the measuring device in the field was 72.5 dB(A). In this case a big agreement of the results of the model in comparison to the field measurements can be noticed. The departures of the equivalent noise levels for short-term measurements were similar as for the situation before the reconstruction and they were up to 1.4 dB(A).

4 Traffic noise mitigation measures

Measures used for the prevention of noise propagation are included into the planned space management while the protection on the immission position is carried out by placing noise protection barriers or by improving the noise insulation of the building. By accepting [6], which regulates planned construction, the city of Zagreb made the first and the most important step in that direction. On the other hand, the construction of noise protection barriers in densely built areas is, due to the lack of space, quite often an inapplicable measure, although a satisfactory decrease in the noise level can be achieved. That is why in urban environments the measures that reduce the noise at source should be preferred. The practice in the majority of European towns [11], which try to reduce the problem of the increased environmental noise levels, is the application of one or more measures.

Noise mitigation measures which could be applied in **the wider city centre as e.g. Location A**, can be observed in two ways: those the application of which is within the competence of city authorities and those which should, in principle, be carried out and financed by the very owners of buildings, possibly in accordance with the financial support of the City. These others include the segment that refers to the protection on the immission position as well as the sound insulation of the building. Traffic noise mitigation measures, except the construction of noise protection walls by, would undoubtedly show significant improvement if their implementation was systematically controlled. Such solutions sometimes require taking measures, which highly exceed the means and capacities of the institutions, which manage the city space and are in charge of protection measures. Their implementation is a long process the success of which depends on the consciousness and the responsibility of all the participants, from city authorities, residents who live in the vicinity of the roads to the drivers who use them. Very frequently, at the expense of such solutions however, where there are spatial capacities, and in the wider centre there usually are, placing of barriers is planned. It should be mentioned that on Location A noise levels are constantly very high and it is not excluded that a satisfactory protection could be achieved without the application of noise protection barriers.

In urban city environments, e.g. **Location B – narrower city centre**, where there are big constructed areas along the roads and where the possibility of placing protection barriers is very small exactly because of the lack of space, a great attention should be paid to reducing the noise level at source. On the example of this location it turned out that the speed limit is regularly not respected and, when allowed by traffic conditions, the speed is higher. Before the reconstruction, due to the damage of the pavement surface, the drivers drove at lower speed because higher speed resulted in unpleasantness; it was dangerous and could cause unwanted damage on the vehicle. With higher speed more closely distributed traffic lights and pedestrian crossings additionally increase the noise level due to starting and stopping the engine. Fully charged parking lots as well as the construction and arrangement of cycling tracks did not result in the decrease in vehicles and using of public city transport and bicycles. The only really implemented measure is the improvement of the pavement surface, and it resulted in the reduction of noise level of only 1 dB(A) in the period day and evening. On the other hand, in the night period this measure leads to the increase of the noise level of 0.7 dB (A). The stated facts show that if the objective is the significant reduction of the noise level in the area of narrower city centre it is not only enough to take technical measures, but also the permanent cooperation of all sides is necessary, both of the residents and the responsible services. Only after the successful implementation of all the planned measures it will be possible to assess whether they brought the expected improvements.

The analysis of the existing and future noise situation, carried out by the presented computation model on **Location C - Comment** which usability was verified by short-term field measurements, is of enormous importance on the way of improving the noise situation and environmental protection as a whole. By using the described model and short-term field measurements as the information for the calculation of the needed parameters the noise levels caused by the change in environmental conditions or the efficacy of the applied protection measure can be predicted with the satisfactory precision even before it is performed in the field. Using such an approach already in the phase of making the project documentation makes the planning of protection measures in urban areas possible.

5 Instead of conclusion

Measures which refer to the decrease in speed, arrangement and change of driving surface, the maintenance of roads and vehicles, the behaviour of drivers and prohibitions and the management of the traffic regarding redirecting and limiting the traffic in time and space would definitely contribute to the decrease of the noise level in the narrower and wider city centre. However, it is not realistic to expect it in the short term. The especially disputable measure is the one of redirecting the traffic for the locations discussed in this paper, that are situated on the main city roads where further increase in the traffic load can be expected. The protection by barriers represents a measure by which a temporary improvement of the situation is achieved and they are presently the most frequent choice in Croatia. The frequency of this measure lies in the fact that, so far, noise protection has been considered and carried out along highways; therefore, there is a certain amount of experience concerning the application of this type of protection measure. Although the pilot project, which is the content of this first phase of research, has only been finished in part, taking certain activities connected to the noise level reduction on certain locations has been initiated in the city administration. Except barriers some other options are considered depending on specific features of urban areas. Regarding the expected further urbanization and development of city areas, which certainly imply, if not the increase in the noise level, then surely the prolongation of the time of exposure, the range of measures will have to be widened in the future in order stop that trend.

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