With the Crowdsourced Spatial Data Collection to Dynamic Noise Map of the City of Zagreb

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Abstract. *The most distinctive examples of non-physical pollution that affects the quality of life in the cities are light and noise pollution. The noise pollution results largely from road and rail traffic in cities affecting directly the health of the citizens. Traffic management, dispersion and diversion, as well as the construction of noise barriers are the measures taken by institutions with the aim to reduce the quantity or impact of noise. According to the applicable laws, all larger cities are obliged to make the noise maps. These are mostly strategic noise maps made tightly focused on a certain source of noise and updated every five years in accordance with the regulations. The question is, however, how to register and present the total emission of noise in a certain area? It can be done with the noise map the production of which is presented in this paper. The map presents the total noise emission in a part of Zagreb, and it has been made by including the community into the collection of data and by means of a free application used for measuring the noise.*

Keywords: *crowdsourcing, noise map, Noise tube.*

1. Introduction

The noise pollution is a large problem in many cities. The noise pollution is mostly the result of road and rail traffic in the cities and it makes a direct impact on the health of the citizens. Traffic management, dispersion and diversion, as well as the construction of noise barriers are the measures taken by the institutions in cities with the aim to reduce the quantity or the impact of noise. In order to make these measures more efficient, the people who make decisions in this respect need the information about the level of noise in single parts and streets of the city. In this respect, the cities prepare the noise maps today [Poslončec-Petrić *et al.* 2016].

Crowdsourcing is by definition the process of selecting the tasks that have traditionally been performed by employees and of outsourcing them to a group of people in the form of an open call [Howe 2006]. In other words, instead of using their own resources, the companies announce the problem online inviting the internet users to help in solving the problem [Roth 2013]. The development and

distribution of mobile telephony has attributed a new significance to *crowdsourcing*. The majority of people have got a mobile phone, mostly a smart phone available today at affordable prices and equipped with many installed sensors (camera, GPS receiver, microphone, proximity sensor, compass, accelerometer, gyroscope, etc.). The mentioned sensors make it possible to obtain various spatial information quickly and simply.

The obligation to produce official noise maps is regulated by law. The paper presents the production of a noise map on the basis of the data collected by citizens.

2. Noise maps

The system of environmental noise management is established by means of strategic noise maps, action plans and conflict noise maps.

Strategic noise maps are the maps that encompass only one source of noise, i.e. road, rail and air traffic, and industry, including also maritime and river traffic along with the accompanying infrastructure, as well as the sport and recreation facilities, etc. Strategic map noise is made for the time of 'day', 'night' and 'evening-night' [NN 75/09].

The action plans are made on the basis of the existing strategic noise maps basically for the purpose of providing a reliable professional presumption for the reduction of noise impact on the people in the areas indicated in the strategic maps as problematic.

Conflict noise map is a distinctive map made on the basis of the produced strategic noise map indicating the difference between the existing and/or foreseen status of noise emission and allowed levels of noise. The conflict noise map is made by means of computer methods in which the allowed levels of noise are subtracted from the level of the existing and/or foreseen status of noise emission.

The documents pertaining to the production of noise maps in the Republic of Croatia are the *Law on Noise Protection* [NN 30/09] and the Ordinance *on the Map Production Methods and the Noise Map Contents, and on Action Plans, as well as on the Methods of Calculating the Allowed Noise Indicators* [NN 75/09]. According to the mentioned Ordinance, the computer methods for calculating and the assessment of the environmental noise are the methods taken over from the guidelines of the European Union about the methods for the calculation of noise in industrial areas, on the main roads, the main railways and airports. The Ordinance also regulates the production and the contents of the strategic noise maps, action plans and conflict noise maps.

By accepting the European legal regulations, the obligation to make the noise maps has also been taken over for cities having more than 100 000 citizens, more important traffic routes and industrial plants producing big noise. Strategic noise maps and action plans are permanently coordinated with the changes in space and implicitly updated every five years. Both documents must be completely available to public in accordance with special regulations pertaining

to informing and participation of public in the issues related to the protection of environment.

2.1. The existing noise maps in the Republic of Croatia

The Law on Noise Protection [NN 20/03] specifies the obligation for the counties, the City of Zagreb, the towns and municipalities to produce the noise maps, and according to the Law, these maps should be an integral part of the information system of the environmental protection in the Republic of Croatia and present a professional foundation for the production of spatial plans. However, according to URL 1, there was no systematic monitoring of noise in the environment and the evaluation of the impact of noise on the health of people in the Republic of Croatia until 2008.

2.1.1. GIS Viewer of Strategic Noise Maps

In accordance with the Law on Noise Protection [NN 30/09, 55/13 and 153/13], the noise maps are the „integral part of the Information System of the Environmental Protection in the Republic of Croatia and present the professional foundation for the production of spatial plans. The Croatian Environment Agency [URL 1] is responsible for the development and management of the Information System of Environmental Protection, and it made the research in 2008 about the status of produced and available noise maps in the Republic of Croatia. The questionnaire of the Environment Agency was sent to all counties, to the City of Zagreb, the towns and municipalities that are obliged to make the Noise map in order to examine the existing situation related to the produced Noise maps [URL 2].

Figure 2.1 GIS Viewer of Strategic Noise Maps (The Strategic Noise Map of Varaždin) [URL 3]

The towns and municipalities that had produced the Noise map in accordance with the Law on Noise Protection [NN 20/03] until do 2008 and delivered the data to the Environment Agency are the following: Varaždin, Sisak,

Mali Lošinj, Bjelovar, Pula, Osijek, Kutina, Delnice, Velika Gorica, and the municipalities Viškovo and Popovača. The delivered maps were included into GIS Viewer of Strategic Noise Maps [Figure 2.1] [URL 3].

GIS viewer was made in 2008, and there are also the noise maps of the counties and the City of Zagreb, the towns and municipalities included into the base presenting the level of noise in inhabited areas produced by traffic (road, rail, air and maritime traffic) and industry.

2.1.2. Strategic noise map of the City of Zagreb

In March 2014, the first strategic noise map of the City of Zagreb [Figure 2.2] was completed. By producing this map, the City of Zagreb has fulfilled the obligation specified by the Law on Noise Protection and by the European Directive on Noise Protection [2002/49/EC], which has laid the foundation for the establishment of noise management system.

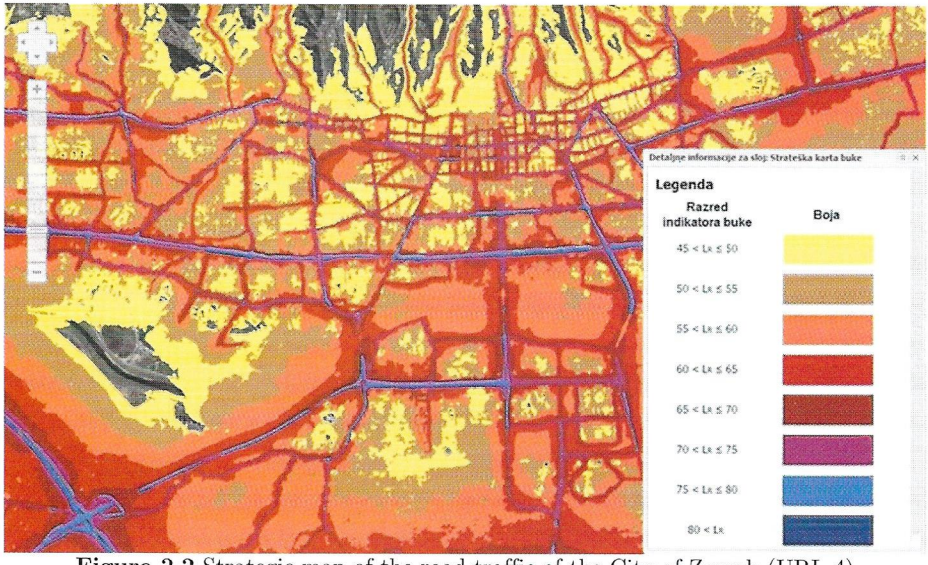

Figure 2.2 Strategic map of the road traffic of the City of Zagreb (URL 4)

The map was made for road, tram and railway traffic, and for the industrial plants. The strategic noise map is available on internet pages of Zagreb Geoportal [URL 4].

3. Dynamic noise map

Dynamic noise map is the map that visualises the level of noise in real time. The production of noise map is possible by including the citizens into the process who act as sensors and measure the level of noise in their surroundings using the application on their mobile phone or some other *smart*-device [Vuković *et al.* 2015a].

The production of the noise map of the city of Zagreb was initially triggered by the participation in the project „i-SCOPE" (interoperable Smart City services through an Open Platform for urban Ecosystem) [URL 5].

3.1. The project i-SCOPE

Within the frame of the programme of the European Commission ICT-PSP (*The Information and Communication Technologies Policy Support Programme*), the project i-SCOPE was initiated in 2012. The project lasted 36 months and was financed with 4.040.000,00 Euro.

The main goal of the project i-SCOPE was to develop and test the technologies used for the services in smart cities by means of specially developed platform based on the open 3D Urban Information Model (UIM). 3D UIM is created by means of geospatial information and can be used for the development of "Smart Internet Services" based on geometric, semantic, morphological and structural data at the city level. The cities can use UIM in better decision making related to urban planning, city management, environmental protection and energy consumption on the basis of samples and morphology, as well as for the promotion of involving various groups of users (e.g. older citizens, or the citizens with various capabilities) through the services that are connected with the obstacles in cities, and of including the citizens in the process of gathering various georeference data related to a certain type of service.

The following three types of services have been developed within the frame of iSCOPE project:

1. the improvement of the mobility of older citizens and the citizens with reduced ability to walk by means of the service of personal directing of movement,
2. the optimizing of energy consumption by means of the service related to accurate assessment of solar potential and energy loss in buildings, and
3. the monitoring of noise by mapping in real time using the application on mobile phone.

Through its City Office for Environmental Protection and Sustainable Development, the City of Zagreb was included into the second and third component of the project, and the students of the Faculty of Geodesy participated actively in the collection of data about the noise using the application on mobile phone.

3.1.1. Noise tube – noise measurement application

Noise tube is a research project that started in 2008 at the Sony Computer Science Lab in Paris and currently maintained by the Software Languages Lab at the Vrije Universiteit Brussel. The NoiseTube project proposes a participative approach to monitoring the noise pollution by involving general public. The NoiseTube mobile app extends the current usage of mobile phones by turning them into noise sensors enabling citizens to measure the sound exposure in their everyday environment [Figure 3.1].

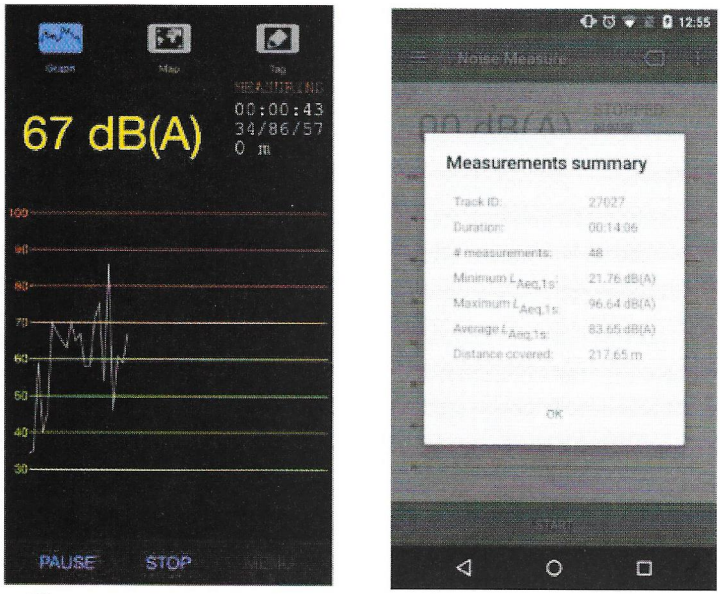

Figure 3.1 Phone as noise sensor: Measuring interface and measurements summary view on Noise tube [URL 6]

Furthermore, each user can participate in creating a collective map of noise pollution by sharing geolocalized measurement data with the NoiseTube community [URL 6].

3.2. Noise measurement and data processing

The students of the Master study programme of geodesy and geoinformatics at the Faculty of Geodesy, University in Zagreb were actively included within the frame of the course Thematic Cartography (ac. year 2014/2015) [Vuković 2015, Vuković *et al.* 2015b], and the course Geovisualisation (ac. year 2015/2016) into the process of mass collection of data for the purpose of monitoring the noise in real time. The measurements processed and presented further in this paper were made by about 60 students with their mobile phones within the frame of the exercises in Geovisualisation.

Every student measured the noise in one of the selected areas at various times of a day [Figure 3.2], and there were 4-5 students performing the measurements for each area.

The measurements were made in October and November 2015 when the weather was nice and sonny, avoiding thus the additional noise produced by rain. The obtained measurements were united and processed. There were 192892 data obtained in 352 measurements for the presented area. The highest level of noise was measured in the area B4 in the morning hours and it amounts to 129.73 dB. The lowest level of noise of 20,025 dB was measured in the evening hours in the area C1 [Table 3.1].

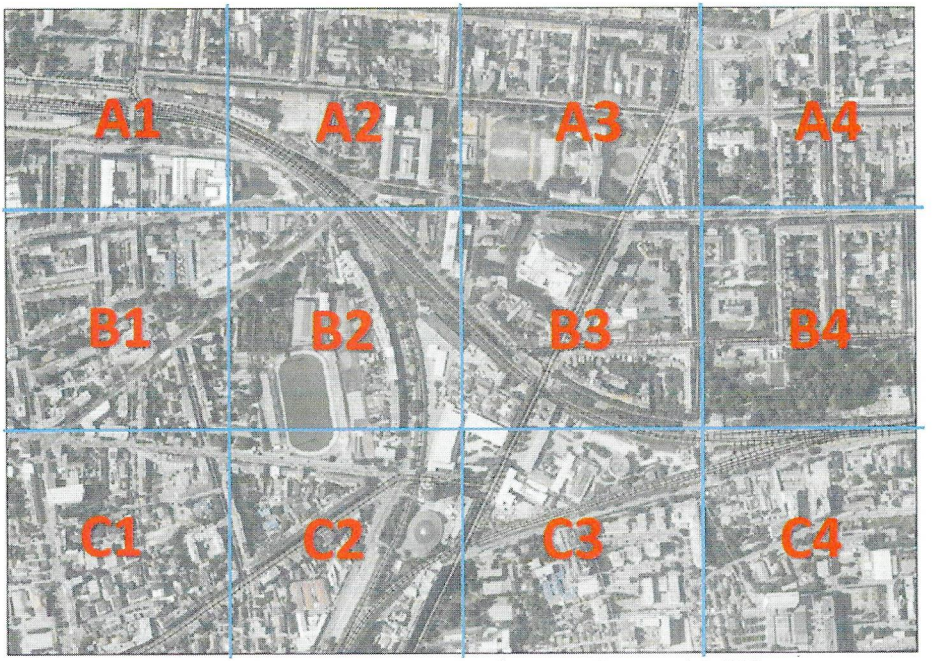

Figure 3.2 The area of survey (sources: Geoportal DGU)

Table 3.1 Noise measurement data

Time of day:	Number of measured levels of noise	Max. value (dB) / area	Min. value (dB) / area
7-12 sati	71594	129.73 / B4	20.039 / C2
13-17 sati	79011	129.53 /C4	20.094 / C2
18-22 o'clock	42287	87.23 / C1	20.025 / C1

The NoiseTube application proved to be very simple for the collection of data about the noise. Still, the user should take care that the satellite receipt is switched on during the measurement, which is needed for positioning and for the access to Internet, otherwise it is not possible to store the data. The mobile devices should also be held horizontally in front of a person, and not in a pocket, on the bicycle or similar. All above mentioned affects the level of registered noise. The students were instructed about these rules before going to the field.

3.3. Noise map made on the basis of voluntarily collected data

The data collected by means of Noise Tube application were downloaded from the web page noisetube.net in *.kml or *.json format, and data processing and the production of the noise maps themselves was made in the programme QGIS.

The analysis of the collected data shows that they are in the range of 20 to 130 dB, and they should be classified into several classes for the purpose of better understanding and faster making of conclusions. In accordance with the Ordinance on the Highest Allowed Levels of Noise in the Areas where people live and work [NN 145/04], the acceptable level of noise in open areas in the city is 40-55 dB. The measurements were classified accordingly. One class encompasses the level of noise of 50 decibels, and the other classes were determined with the interval of 10 decibels with a certain colour attributed to each class. The class borders and colour scale are presented in the figure 3.3.

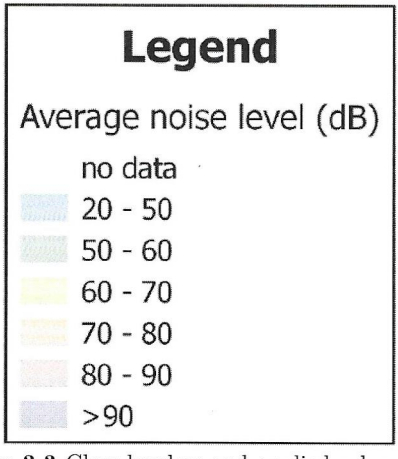

Figure 3.3 Class borders and applied colour scale

Since there was a large quantity of collected data, we wanted to present the change of the level of noise in the selected area of Zagreb in various periods of a day. The data were thus divided into three periods of a day, i.e.:

- morning and forenoon (from 7 to 12 o'clock) [Figure 3.4],
- afternoon (from 13 to 17 o'clock) [Figure 3.5], and
- evening (from 18 to 22 o'clock) [Figure 3.6].

The visualisation of the measured level of noise provides at first sight the general conclusions about the area, as e.g. whether the area is burdened with traffic infrastructure and exposed to permanent noise, or it is the area of some peaceful part of the town away from traffic routes and other sources of noise.

There are the produced noise maps presented below related to specific part of the City of Zagreb according to the mentioned classification. Figure 3.4 presents the noise map of one part of Zagreb for the period from 8 to 12 o'clock, figure 3.5 presents the noise map of one part of Zagreb for the period from 13-17 o'clock, and figure 3.6 the noise map of one part of the City of Zagreb for the period from 18 to 22 o'clock.

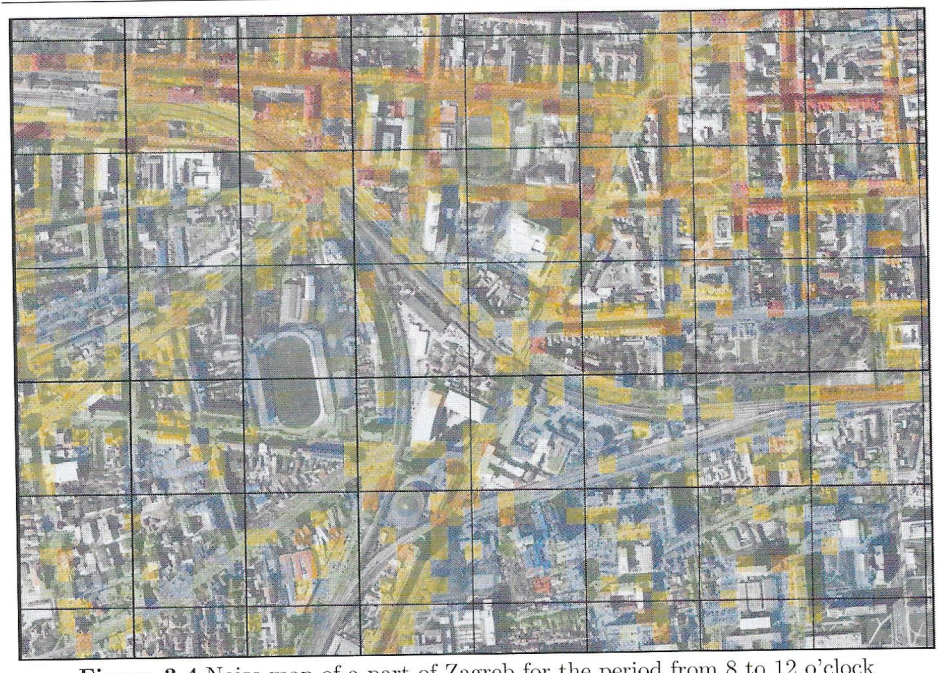

Figure 3.4 Noise map of a part of Zagreb for the period from 8 to 12 o'clock

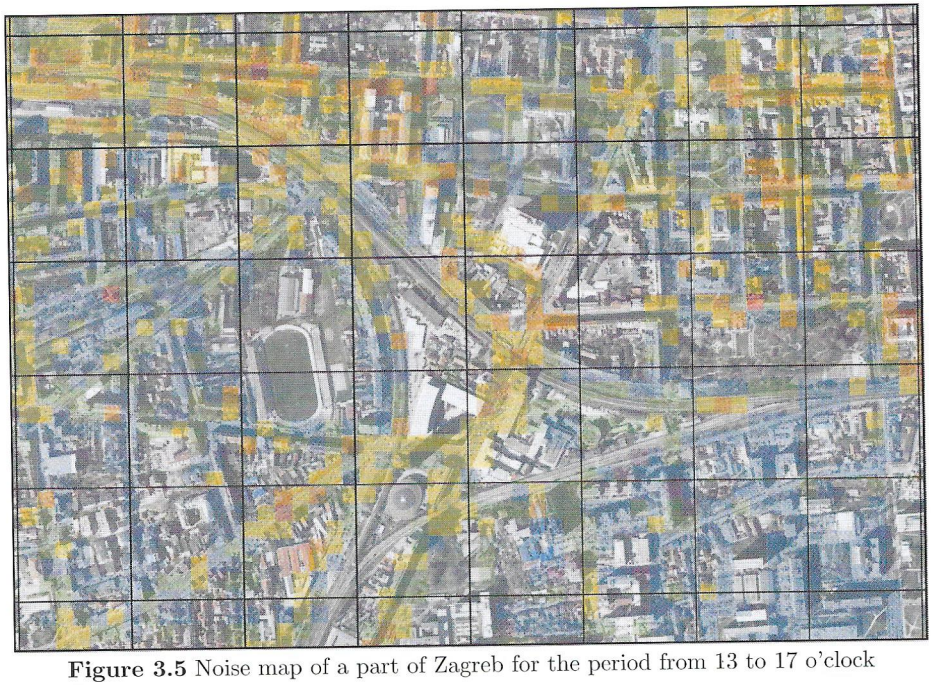

Figure 3.5 Noise map of a part of Zagreb for the period from 13 to 17 o'clock

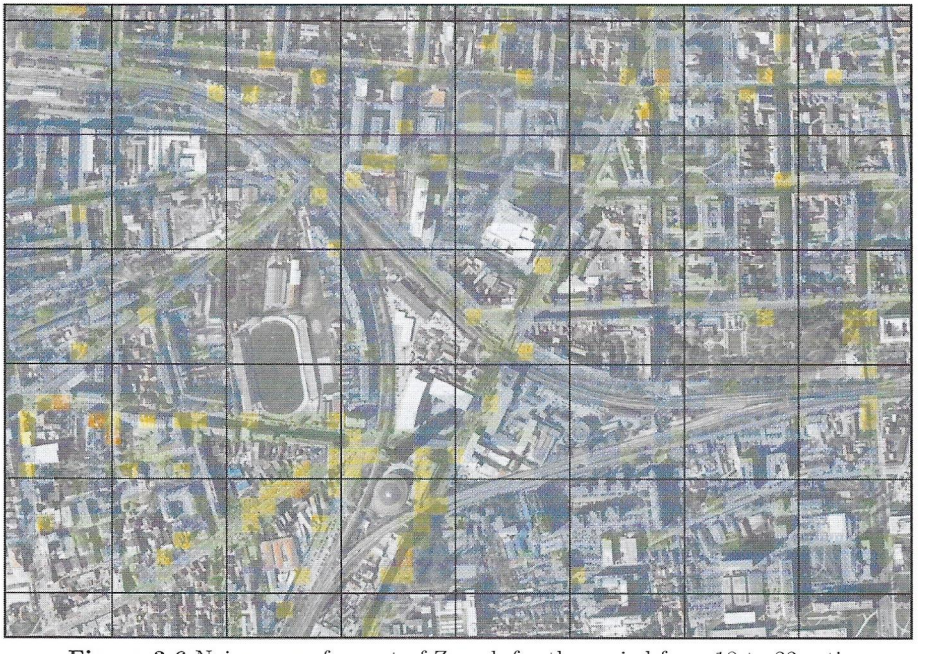

Figure 3.6 Noise map of a part of Zagreb for the period from 18 to 22 sati

It is evident from the figures 3.4, 3.5 and 3.6 that the largest noise in the part of the City of Zagreb for which the noise map was made is caused by road traffic. According to the measurement data, the presentation along the busiest city roads (so called green wave) indicates high levels of noise in the forenoon hours [Figure 3.4]. However, comparing the figures 3.4 and 3.5, we can see that there are individual deviations from the expected values. In the town centre itself, a significant reduction of the level of noise can be noticed in the afternoon hours (13–17 o'clock) compared to the morning and forenoon hours.

In the evening hours (18-22 o'clock) [Figure 3.6], the level of noise in the observed area is acceptable and meets the recommendations according to the Ordinance [NN 145/04].

4. Conclusion

The noise map described in this paper was made by means of a free application for the noise measurement, a free programme for data processing, and of the device owned today by the majority of citizens, and by engaging the students who collected the data walking around the town.

The greatest advantage of the described model is related to the fact that the obtained presentation offers a real and comprehensive illustration of the noise pollution in the area (with the reference to all noise sources). Official noise maps are made for individual noise sources, and the total quantity of noise that the citizens are exposed to is not presented.

The other advantage is related to the fact that the map can be made by engaging the community, when necessary. The strategic noise maps are made every 5 years, and during that period, many significant changes can occur in the area that can affect the increase of noise pollution.

Although the noise map made in this way cannot replace the official noise maps, it can certainly point out the problems related to the noise in certain areas neglected by the strategic noise map because they are not related to the targeted source of noise, and it can highlight some newly created noise pollutions in the environment.

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Masovnim prostornim podacima do dinamičke karte buke grada Zagreba

Sažetak. *Najizraženiji primjeri nefizičkog zagađenja koje utječe na kvalitetu života građana u gradovima su svjetlosno i zvučno zagađenje. Zvučno zagađenje rezultat je u najvećoj mjeri cestovnog i tračničkog prometa u gradovima i direktno utječe na zdravlje građana. Upravljanje prometom, disperzija i preusmjeravanje prometa i izrada zaštitnih pregrada mjere su kojima institucije gradova djeluju na smanjenje količine ili utjecaja buke. Sukladno važećim zakonima, za sve veće gradove postoji obveza izrada karata buke. Najčešće se radi o strateškim kartama buke koje se izrađuju ciljano prema određenom izvoru buke i sukladno zakonima, obnavljaju svakih pet godina. Međutim, postavlja se pitanje, kako registrirati i prezentirati ukupnu imisiju buke u određenom prostoru? To je moguće kartom buke čija je izrada prikazana u ovom radu. Karta prikazuje ukupnu buku na dijelu grada Zagreba, a izrađena je na temelju uključivanja zajednice u prikupljanje podataka i slobodne aplikacije za mjerenje buke.*

Ključne riječi: *karta buke, masovno prikupljanje podataka, Noise tube.*

****scientific paper***