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# MAPPING NOISE POLLUTION WITH OPEN-SOURCE GIS

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***Abstract***

*As a result of the growing population density in urban areas, environmental noise is nowadays recognized as a public health problem. Directive 2002/49 / EC require the creation of noise maps in the main European cities. Sound is an elastic wave that propagates in a gaseous, liquid, or solid medium. Noise is a complex of sounds of different frequencies and intensities randomly superimposed. The production, propagation and detection of sound waves are related to the vibration of the elastic environment, which the human ear can detect. Now in the "century of speed" when development is the priority, urban areas are the most affected. In this study, we have determined and map the noise pollution levels in a crowded intersection in Bucharest. The values obtained were compared with the limits presented in the current legislation - SR 10009:2017 for the noise level. Obtained data were processed, and noise pollution levels were mapped using a geostatistical analysis software - QGIS software.*

***Key words****: noise mapping, QGIS software, traffic noise pollution.*

## INTRODUCTION

The acoustic noise has been recognised by European Environment Agency the main hazards for human health in urban areas. It is estimated that more than 100 million people are daily exposed to dangerous noise levels (European Environment Agency, 2020). In 2002, the EU issued the Environmental Noise Directive 2002/49/EC in which the countries are obliged to draw strategic noise maps in each city exceeding 250000 inhabitants, for all major roads which have more than six million vehicle passages a year, major railways airports within their territories.

The aim of the Directive is: "to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise".

Urbanization create environmental problems, like air pollution (Yuan Song et al., 2014), heat island effect (Liu, 2018; Virsta, 2012), loss of biodiversity (Cardinale et al., 2012), soil contamination (Sandu, 2013) and sound levels which are above the permissible limits (Halonen et al., 2016; Oyedepo, S.O., 2012; 2013).

This pervasive pollutant is expanding in scope and intensity commensurate with human population growth and urban development (Slabbekoorn and Ripmeester, 2008).

In urban area, one of the most common pollutants is the persistent noise (Gidlöf-Gunnarsson and Öhrström, 2007; Rosca et al., 2019).

To better understand this topic, it is necessary to differentiate "sound" from "noise".

Sound is a disturbance that is propagated through an elastic medium (air, water, etc.), at a speed that is characteristic of that medium. Sound is determined by vibrations emitted by a sound source, such as a machine, a loudspeaker, or a human voice box. The decibel scale is corrected to represent the auditory sensation, originating the A scale; the unit of measurement is called dBA.

Sounds called "noise" are usually sounds that we perceive as unpleasant or disturbing, although the physical properties of noise are the same as those of sound. Noise can cause symptoms of stress, ringing in the ear, pain, and high risk of heart disease. High-frequency noises are the most harmful to hearing and, as a result, are the main cause for concern.

Noise is a complex of sounds without a periodic character, with random disagreeable insurgency,

affecting the psychological and biological state of people and other organisms in nature.
The direct impact of environmental noise on humans, as well as on ecological heath, is severe. According to World Health Organization noise pollution caused by traffic (cars, trains, and planes) is the root of diseases, dysfunctions, and premature deaths (WHO, 2011). The noise produced by the means of transport can cause various disorders, from insomnia to heart attacks, learning problems and tinnitus (ringing in the ears). The World Health Organization has warned that noise caused by road traffic is "the second favorable environmental factor of illnesses", after air pollution (WHO, 2011), (Figure 1).

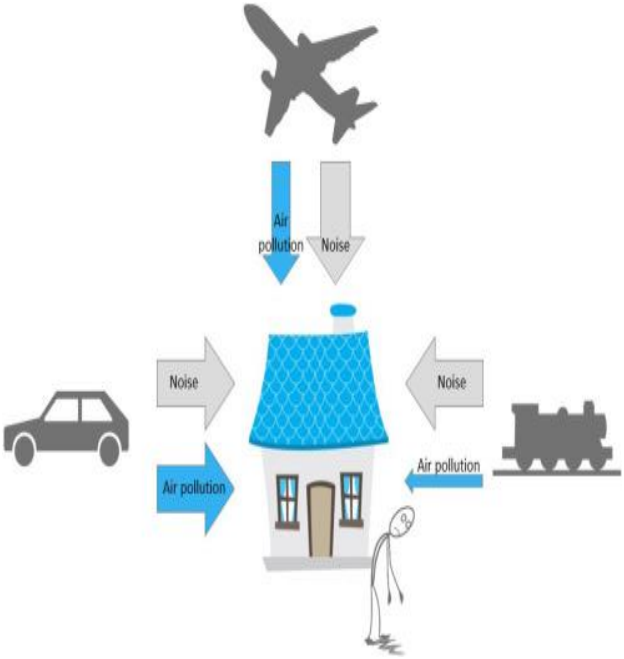


Figure 1. Relative contributions from noise compared with air pollution at the residence for three modes of transportation: road, rail, and aircraft. The size of the arrows illustrates how closely the two exposures correlate at the residence for each of the three transportation sources (Mark J. Nieuwenhuijsen, 2020)

Chronic noise exposure for individuals living near major transportation routes (Figure 2) has been associated with depression and feelings of aggression (Stansfeld and Matheson, 2003).

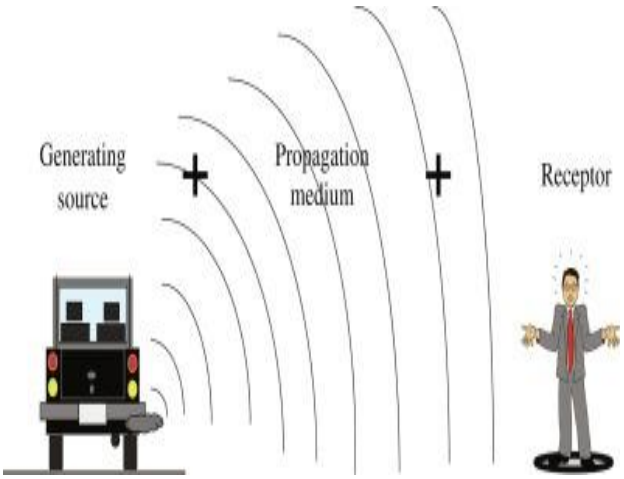


Figure 2. Sound propagation and perception (D'Agosto, 2019)

Seong et al. (2011) describe environmental noise assessment and mapping as the presentation of predicted or measured noise data, indicating breached thresholds together with an estimation of people exposed. There are several noise prediction models designed for assessing environmental noise whose application is largely dependent on the country in question as well as the traffic and environmental characteristics.
In the context of the Directive 2002/49/EC, noise maps are the main tool for investigation and decision-making in the implementation of action plans to reduce noise pollution (EC, 2017). Noise map provides detailed information of noise environment and it is an efficient tool for visualizing noise level in colors (Bouzir and Zemmouri, 2017).
Open source-GIS tools have in recent years increased in popularity. A contributing factor to this development is the optimized handling of datasets which in the case of environmental impact and assessment studies is often of large spatial and temporal extents. A unique strength of open-source methods is the ease of replication through the sharing of methods used. Through this, their capability and functionality are quickly enhanced because of their crowd-sourced nature.
In Romania the problem of noise pollution is widespread and high level of environmental noise reduces the quality of living (Figure 3).

| | Lden >= 55 dB | | | Lnight >=50 dB | | |
|---|---|---|---|---|---|---|
| | 2007 | 2012 | 2017 | 2007 | 2012 | 2017 |
| **Road** | 2.879.000 | 2.511.100 | 2.752.700 | 2.056.500 | 2.090.900 | 1.956.700 |
| **Rail** | 273.100 | 275.400 | 96.700 | 206.000 | 241.600 | 93.500 |
| **Air** | 25.800 | 44.300 | 3.500 | 27.700 | 27.400 | 13.300 |
| **Industry** | 90.400 | 230.700 | 15.800 | 50.400 | 64.000 | 7.100 |

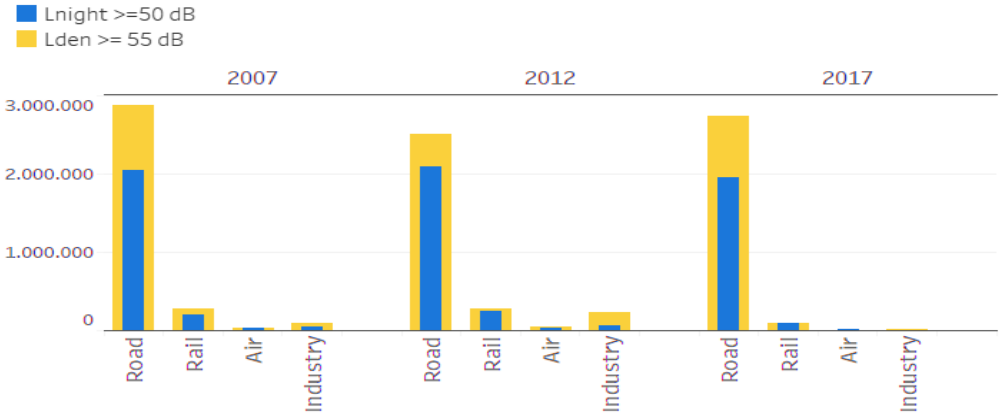


Figure 3. Number of people exposed to high noise levels in Romania (Romania noise fact sheet 2021)

## MATERIALS AND METHODS

Bucharest, the capital of Romania, was selected as the study area. The City of Bucharest is characterized by a high level of noise pollution, reflected on to the inner and outer habitat comfort and the health state of the population. This high level of noise pollution is determined by the road and tramway traffic (Patroescu et al., 2002; Moscovici et al., 2015).

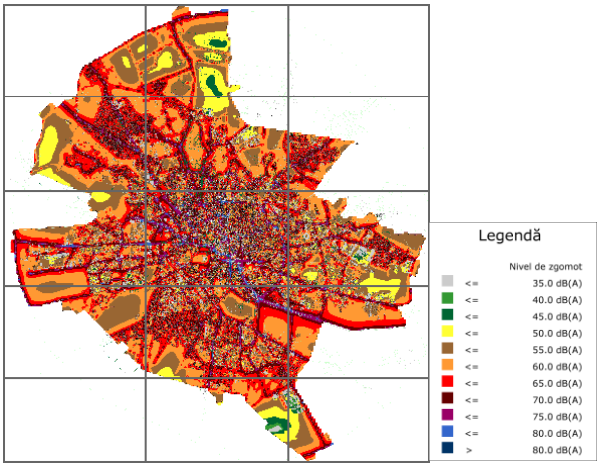


Figure 4. Bucharest road traffic noise map (https://hartiacustice.pmb.ro/)

As can be seen in Figure 4, the centre of Bucharest is constantly "polluted" with an average of over 70 decibels per day. Bucharest City Hall count 228 "conflict zones" - more precisely, 394 streets - in which the noise exceeded 70 dB during the day and 60 dB at night.

As presented in Figure 5, this study focused on the intersection of Timisoara Boulevard with Brasov Street, near Plaza Romania Mall, Bucharest, District 6.

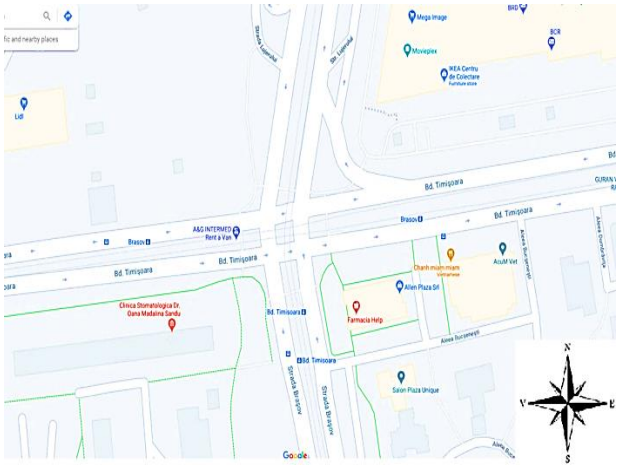


Figure 5. Study area on noise level (road intersection)

To create noise maps with the use of open-source tools, a methodology, organized in three phases, as shown in Figure 6.
The sound level meter model used to measure sound waves is the EXTECH - model 407730 (Figure 7). It is commonly a hand-held instrument with a microphone. The diaphragm of the microphone responds to changes in air pressure caused by sound waves. That is why the instrument is sometimes referred to as a Sound Pressure Level (SPL) Meter.

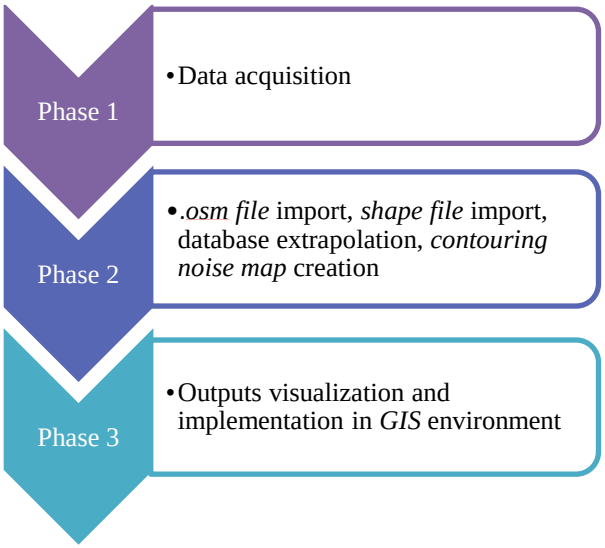


Figure 6. Methodology diagram


Figure 7. Sound level meter - EXTECH - model 407730

Sound meters are frequently used in acoustic pollution studies to determine almost any type of noise, but especially for the industrial, environmental and airport noise fields.
The sound-level meter is designed to respond to sound in approximately the same way as the human ear, with a view to obtaining objective, reproducible measurements of the sound pressure level. With its help, through repeated measurements, a noise map of a locality or area can be obtained.
The measurements were taken at street level (at road junctions, market centres, and residential areas). The sound level was recorded in 39 points in the afternoon on January 15, 2021, when the peak traffic was in full swing.
The instrument was held comfortably in hand with the microphone pointed at main source of noise (SR ISO 1996-1 regulation). During the sound measurements, road and tram traffic monitoring was realized, as this source of noise was considered the most important.
The Geographical Positioning System (GPS) points were also collected for each location for accurate coordinates of the sampling points for the purpose of noise mapping. The noise descriptors for the selected location are presented in Table 1. Each value in the table represents an average of 2-3 measurements made in a maximum interval of 1 minute, to establish the best value corresponding to the situation.

Table 1. The sound level in Timisoara Boulevard with Brasov Street

| No. | Decibels (dB) | Latitude | Longitude |
|---|---|---|---|
| 1 | 54.8 | 44.426871 | 26.034131 |
| 2 | 52.2 | 44.426912 | 26.034501 |
| 3 | 56.7 | 44.426739 | 26.033767 |
| 4 | 58.2 | 44.427184 | 26.035085 |
| 5 | 57.8 | 44.427004 | 26.035139 |
| 6 | 65.2 | 44.426778 | 26.032708 |
| 7 | 61.9 | 44.426974 | 26.034265 |
| 8 | 65.1 | 44.427889 | 26.033822 |
| 9 | 62.7 | 44.428278 | 26.03384 |
| 10 | 67.5 | 44.42667 | 26.032892 |
| 11 | 65.6 | 44.426964 | 26.032359 |
| 12 | 69.3 | 44.427002 | 26.033424 |
| 13 | 70.3 | 44.427701 | 26.033709 |
| 14 | 67.3 | 44.427644 | 26.034575 |
| 15 | 72.5 | 44.426979 | 26.033017 |
| 16 | 71.3 | 44.427182 | 26.032505 |
| 17 | 74.9 | 44.426804 | 26.03349 |
| 18 | 71.8 | 44.428062 | 26.033687 |
| 19 | 74 | 44.427602 | 26.034163 |
| 20 | 74.5 | 44.427275 | 26.03382 |
| 21 | 72.4 | 44.427234 | 26.033365 |
| 22 | 77.2 | 44.427207 | 26.032958 |
| 23 | 80.2 | 44.427192 | 26.032735 |
| 24 | 75.7 | 44.427318 | 26.034163 |

| | | | |
|---|---|---|---|
| 25 | 78.3 | 44.427394 | 26.033481 |
| 26 | 76.8 | 44.427521 | 26.033337 |
| 27 | 80.5 | 44.427439 | 26.0327 |
| 28 | 86.2 | 44.427463 | 26.032923 |
| 29 | 90.1 | 44.427298 | 26.03294 |
| 30 | 99 | 44.427357 | 26.033131 |
| 31 | 92.6 | 44.427336 | 26.032843 |
| 32 | 94.8 | 44.427313 | 26.032604 |
| 33 | 79.9 | 44.427389 | 26.033454 |
| 34 | 85.3 | 44.42742 | 26.033695 |
| 35 | 92.6 | 44.427573 | 26.033162 |
| 36 | 90.8 | 44.427707 | 26.033195 |
| 37 | 88.4 | 44.427218 | 26.033156 |
| 38 | 85.1 | 44.427074 | 26.033198 |
| 39 | 87.9 | 44.426908 | 26.033259 |

For the calculation we used QGIS (https://qgis.org/en/site/forusers/download.html).
The calculation was performed only for educational purposes.
The necessary steps to draw up a noise map in QGIS:

1. The data taken must be entered in Excel and saved in "CSV" format to be used in QGIS.
2. First, a "base map" is required. This requires the use of the "QuickMapServices" or OSM plugin (as it is called in the toolbar). The plugin may already exist in the program, or it will have to be installed separately, from the menu bar of the program. After opening the plugin, you can search for the reference area (Figure 8).
3. After selecting the work area, the data taken in CSV format from Excel is added. To add the Excel table opens the "Open Data Source Manager" menu. Enter the table with the data and press the "Add" button to place the reference points over the base map. After adding, the dots will appear on the map (Figure 9).
4. Then from the "Layers" tab with double click opens the properties window of the data table. Here the "Heatmap" variant is selected to highlight the propagation of the sound on the map. The radius of the points must be selected, for this there are 2 variants: the separation of the data into intervals, each interval corresponding to a table and a corresponding radius for that decibel range; or keeping a single table in which, the decibel ranges will be approximated by separate colors (example: green for 50-60 dB or red for 80-90 dB). The points will have a longer radius depending on the decibel level measured at that point and the selected radius. In addition to all this, it will be selected from the option "Weight points by" column in the table that represents the decibel values.
5. Finally, after adjusting the transparency of the points to be able to see the basic map, adjusting the reference scale and selecting the desired colors.

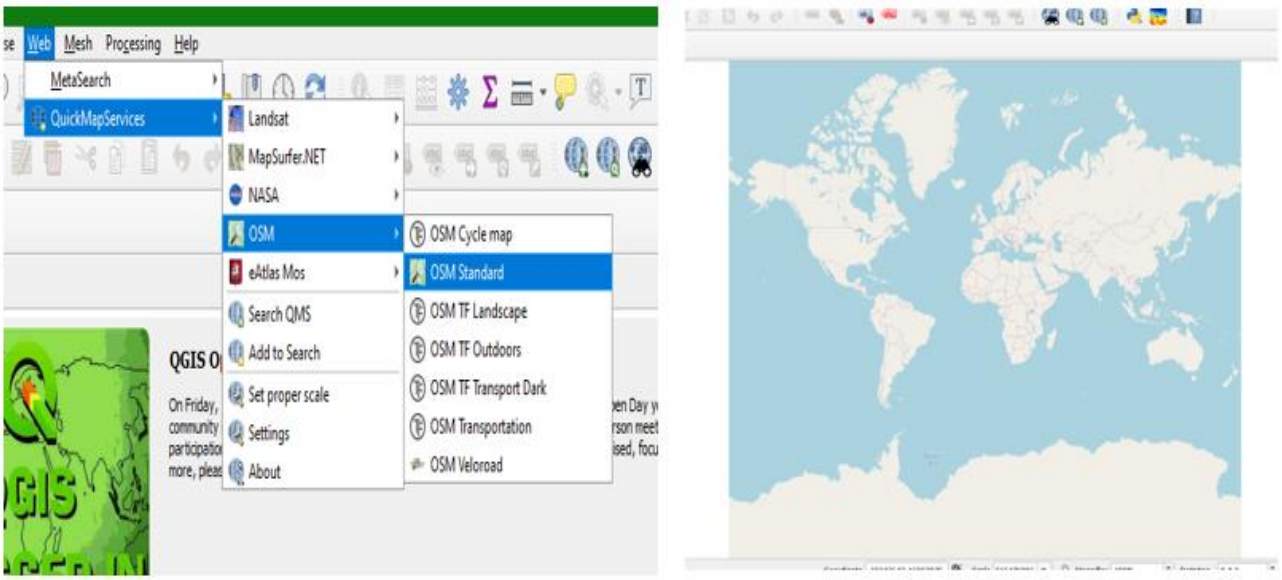


Figure 8. OSM plugin

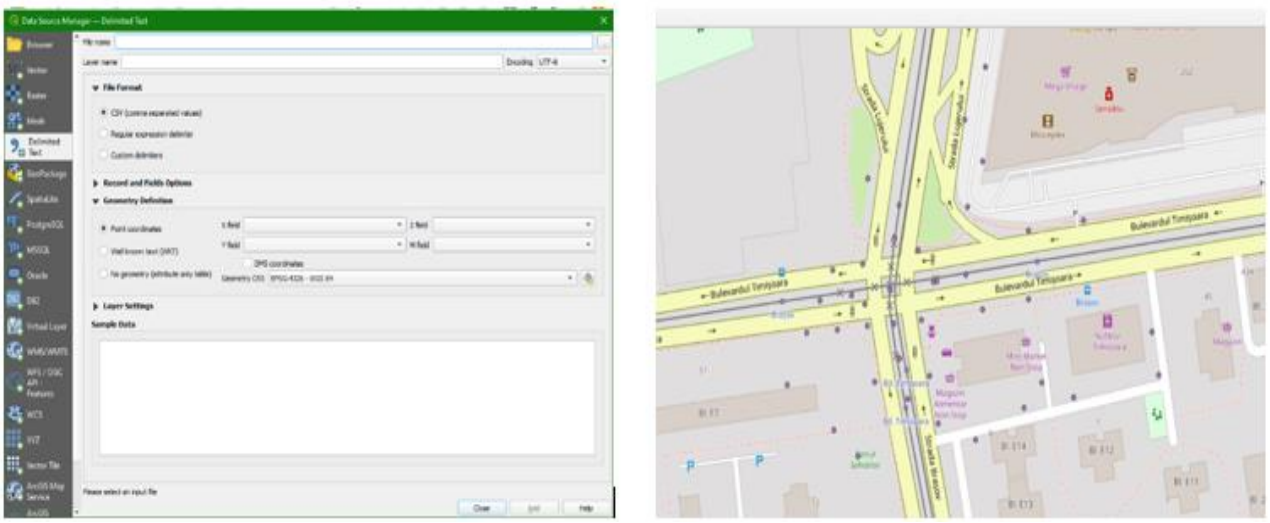

Figure 9. Data Source Manager menu and measured points on the map

## RESULTS AND DISCUSSIONS

The spatial variation mapping of noise levels in Timisoara Boulevard with Brasov Street is presented in Figure 10. The value of noise ranged from 52.2 dB to 99 dB. Monitoring points over 55 dB accounts for round 95% of the study area. According to the limits presented in the current legislation: SR 10009:2017 for the noise level for urban areas in the Romania, noise intensity should be 55 dB in the daytime. The obtain results show that most of commercial and residential regions surrounding the main streets are suffering from severe noise pollution.

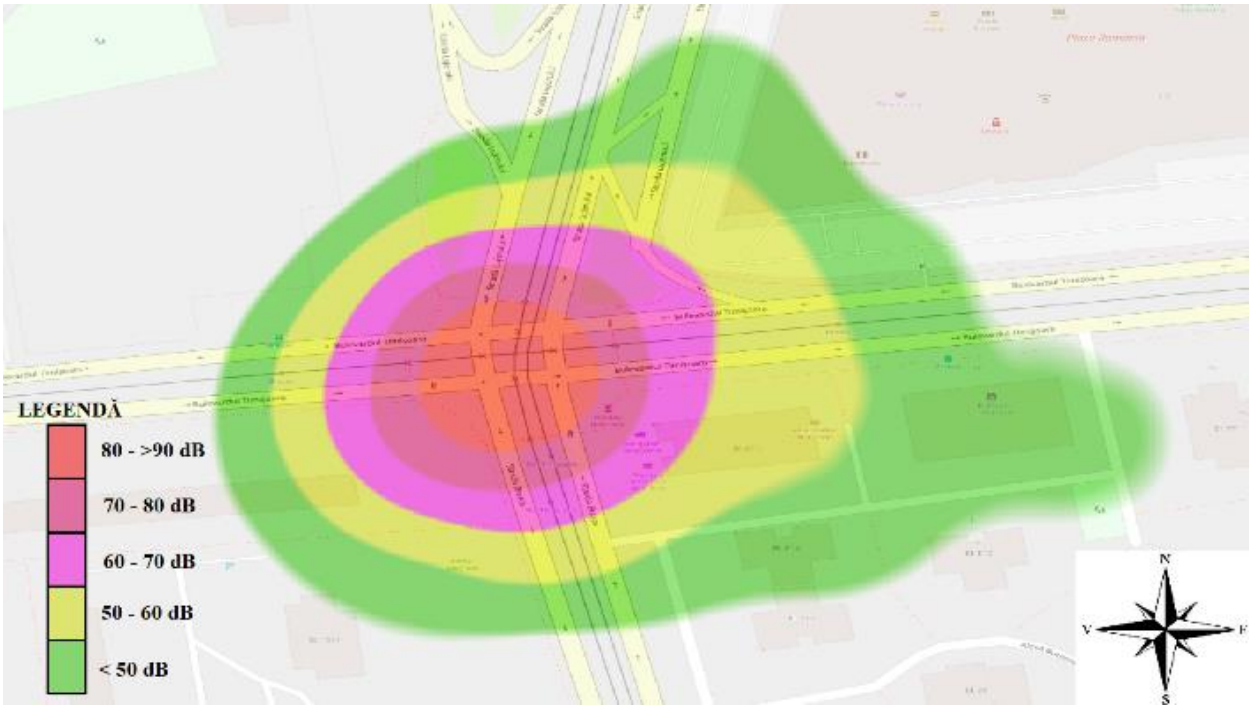


Figure 10. Spatial variation mapping of noise levels in Timisoara Boulevard with Brasov Street

## CONCLUSIONS

To exemplify the noise pollution in Bucharest, a noise map of an intersection was map mapped. Results of this study show that in Timisoara Boulevard with Brasov Street the noise pollution by means of sounds exceeding the level of 55 decibels in daytime (Lden >=55dB). The causes of noise pollution are traffic. These sounds turn

into noises that bother people throughout the day.

It could be clearly seen that people passing through that intersection are exposed to a noise between 65 – 85 dBA. If we move a few tens of meters away (on the sidewalk), sellers at kiosks or nearby shops can be exposed to a noise of 60 – 70 dBA. Even if the buildings still protect them to some extent, no one can just sit locked between "four walls".

To solve the problems from Bucharest related to the noise pollution the proposed methods are:

- applying a law to reduce the noise edge of motor vehicles and the development of quieter cars,
- imposing fines for excessive speed and implicitly for producing unnecessary noise in traffic,
- placement of green barriers in areas with an increased share of noise pollution,
- placing sound-absorbing or sound-insulating panels where infrastructure permits, such as on bridges or overpasses,
- the regulation of road traffic on different routes differentiated on categories of vehicles, so that the trucks, which produce a higher noise, interact as little as possible with the internal areas of the cities,
- speed limitation in certain areas,
- penalties for the drivers that abusively use the horn inside the city,
- prioritize public transport and cycling,
- construction of special lanes for bicycles/scooters,
- constructions and buildings protection measures (phonic isolation),
- urban planning,
- raising population's awareness on the medical problems caused by the noise pollution after long periods of exposure.

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