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THE URBAN ACOUSTIC ENVIRONMENT - A SURVEY FOR ROAD TRAFFIC NOISE

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Abstract: The paper provides results achieved during the research on the assessment and prediction of the urban noise in the city of Cluj-Napoca, a big economic, educational and cultural center in Romania, by respecting the laws in force related to the noise mapping. The examined noise source is the road traffic. The working method included noise measurements and also the generation of noise map by computer simulation with CadnaA software. Measurements of road traffic noise in 96 locations distributed on residential districts of the city, during September-November 2006, indicated that the noise levels in the city exceeded 60 dB(A) in all the measurement locations and that in 70% of them the recorded noise level was over 70 dB(A). A case study for noise and traffic evolution over a period of ten years (2001 – 2010) is presented, for one of the main streets in the city. The noise map associated to its area showed that the admissible levels for L_{den} (70 dB) and L_{night} (60 dB) indicators, established by Romanian legislation were overlapped on the entire length of the street. With the help of CadnaA software it was possible to verify the influence of different input data on the resultant noise map. Some strategies have been analyzed, in order to find solutions for reducing the noise on the delimitated area: no heavy vehicles, speed limitation up to 40 km/h, traffic reduction and change of road surface from smooth asphalt to porous surface.

Keywords: Acoustic environment, Noise pollution, Traffic noise, Noise mapping, Noise prediction

1. INTRODUCTION

Many recent studies have released that urban areas are extremely affected by noise pollution produced by the combination of four main noise sources: the road traffic, the railway traffic, aircrafts and the industrial activities. The key issue in a city is the road traffic noise, representing one of the main factors that influence the quality of life. A lot of publications give specific results observed and obtained during different urban noise surveys, made in specific conditions, legislation and source situations and also explain the gained experience. There is a large range of issues studied, such as:

- legislation, calculation algorithms, propagation models, methods and techniques for urban noise evaluation and prediction (Steele, 2001; Peretti et al., 2006; Bento Coelho, 2007; Can, 2008; Lakusic & Dragcevic, 2008; King & Rice, 2009);
- harmful effects of noise exposure: the social model, the economical model, the medical model, relationship between noise and non-auditory effects (Bluhm, 2004; Ohrstrom, 2005; Muzet, 2007);
- action plans for reducing and control the urban noise pollution, from the point of view of: the noise source, propagation path, human receiver (Manuel, 2005; Kang, 2006; Mrkajic et al., 2010).

Today urban areas are complex environments: residential, industrial, cultural, scientific, educational, commercial and administrative, having a large communication network including internal and external roads in continuous development. The pertinent assessment of noise in such multiple sources and paths context imposed the development of software and computer applications for noise-mapping (ex: SoundPlan, Lima, Cadna, IMMI, NoiseMap), in relation with the growing impact of digital maps and geographical information systems. They implement different noise calculation models and can be used for noise evaluation and prediction, mainly in association with actions of urban planning. The main task in urban noise assessment is to establish or to predict the distribution of noise and to give most appropriate solutions for obtaining a comfortable environment.

All the actions in this area of interest focus on people and the challenge is to improve the noise comfort and to reduce the harmful effects. Factors like: attitude, habits, anti-pollution education, may be taken into consideration in order to define zonal exposure models. These may have different time evolutions, in a similar noise context, and the solutions for reductions of noise exposure must take into consideration the specificity of each model.

The paper presents general aspects of urban noise situation in Romanian cities and also specific results of noise assessments and studies conducted by the authors in the period 2001-2010 in Cluj-Napoca, one of the biggest economic, educational and cultural centers in Romania, with an estimated population of 395 thousands inhabitants.

2. NOISE SITUATION IN ROMANIAN CITIES

Romania was later integrated in the actions related to the assessment and reduction of noise exposure in urban environments, developed within the European space in the last few years, but equal confronted with these problems, having to recover in this area in terms of work experience and development of its own model of noise exposure, which takes into account the specific conditions. Romania does not have a national methodology for the assessment and prediction of the environmental noise. Therefore, the Romanian legislation in this field recommends the use of interim computation methods for the noise made by activities from industrial areas, roads, railway and aerial traffic beside airports. In terms of prediction, it is important to have a collection of data which provides an overview of the evolution in time of the traffic and urban noise and which can be used as starting point for developing new scenarios.

Last ten years were characterized by a continuous growing of noise pollution in Romanian urban environment, the main causes being the increase of the road traffic flow. A growing dynamic was observed, from year to year, for the traffic flow on almost all roads, the main causes being the continuous increase in motor vehicle fleet and reorientation of transport for people and goods from the rail transport to road transport. The noise mapping actions conducted starting within autumn 2006 in nine Romanian cities having more than 250 thousand inhabitants, have demonstrated that the maximum noise levels during daytime frequently overlap 70 dB along the streets of large cities and in lot of residential areas recorded levels are between 60 and 70 dB. The annual report on the state of the environment in Romania for the year 2006, developed by the National Environmental Protection Agency (www.anpm.ro) showed that noise measurements recorded in different cities indicated exceeding of legal accepted maximum values in many evaluation points:

- exceeding between 19-25 dB(A), during day and night, on streets of technical category two (intense traffic, having four circulation tracks);
- exceeding with about 20dB(a) during the day and 15dB(A) during the night, on streets of technical category three (normal traffic, having two circulation tracks);
- exceeding with about 8dB(A) during the day and 4dB(A) during the night, on streets of technical category four (reduced traffic).

Studies on environmental noise and its harmful effects have been done in several big cities (ex: Bucharest, Timişoara, Cluj-Napoca) before 2006, but it must be pointed out that noise assessments were mainly based on noise measurements and results were presented as numerical data, without respecting a common methodology.

The authors have been involved in the study of noise environment in the city of Cluj-Napoca, since 2001, when a database was first created, containing noise and traffic data and also people response and reactions. Even the situation in the city is described now by the noise map developed in 2007, knowledge of time-evolution of the noise situation is important for finding best solutions for its reduction.

3. NOISE CHARACTERISTICS OF CLUJ-NAPOCA CITY

During September - November 2006 a traffic and noise assessment was conducted in the city (Popescu, 2007), as part of achieving the noise map. A total number of 240 measurements were recorded, in 96 locations distributed on residential districts of Cluj-Napoca city, by respecting the same general procedure. Each noise measurement had the duration of at least three hours. Measurements were grouped in three time-intervals, defined by the following hours during a daytime period: 7:00-11:00 (morning), 11:00-15:00 (noon), 15:00-19:00 (afternoon). At each measurement location, both noise level and traffic flow and composition were recorded. During the three hours noise measurement period, the numbers of light vehicles and heavy vehicles per hour, passing on the road, were counted. The average traffic speed on each road segment was estimated for light and heavy motor vehicles.

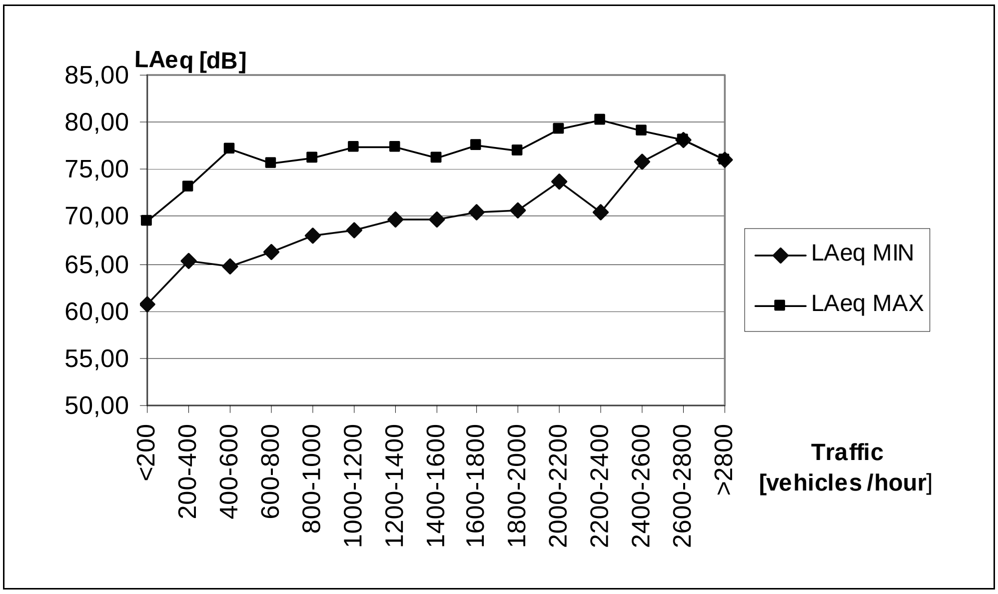

Figure 1. Recorded LAeq on streets with different traffic volumes

Results of noise and traffic assessment are presented in figure 1. Measurement points are represented on the horizontal axis, grouped in 15 traffic volume intervals, starting with the streets having less than 200 car passages per hour, and ending with the streets having more than 2800 car passages per hour. We must specify that in 70% of total 96 locations the counted traffic was between 400 and 1600 motor vehicles per hour, during the daytime, and that in 20% of total locations the counted traffic volume was over 1600 motor vehicles per hour.

Noise and traffic measurements showed that the equivalent noise level exceeded 60 dB(A) in all the 96 individual locations (Fig. 1). In 70% of measurement locations the recorded equivalent noise level was over 70 dB(A). The comparison of these results with those obtained during a noise study performed in Cluj-Napoca during 2000-2001 indicates a significant increase of traffic and also noise on the most city roads, not only in the central area of the city, but also in the residential and industrial areas.

The number of inhabitants exposed to different levels of road traffic noise is presented in table 1, as it was calculated based on the noise map of the city. Besides, information on noise maps of the nine cities can be found on the website of each town and also in NOISE database (Noise Observation and Information Service – http://noise.eionet.europa.eu).

In 2009, the annual report on status of environmental factors for 6NV region, developed by the National agency of environmental protection, contains information about monitoring measurements conducted during 2009 in Cluj-Napoca. From 122 measurements of road traffic noise, 81.97% were over the admissible value, and the maximum recorded noise value was 96,4 dB.

Analyzing measurements and observations in the city, the following particularities and deficiencies were noted:

- The road network in the city is dimensioned for a lower traffic; the central part of the city has narrow streets, with over fulfilled traffic capacity;
- Heavy vehicles are passing through the city, in the absence of adequate way rounds;
- Vehicles parked on no parking spaces, most on both sides of roads, reduce the available streets width;
- Road structure works conducted during daytime, which generate slow traffic, blockages and redirected routes;
- Intersection blockages due to an inadequate traffic management;

Table 1. Number of inhabitants exposed to road traffic noise – Cluj-Napoca City
(Source: http://www.primariacj.ro/docs/)

Level of noise [dB]	Number of person exposed to noise	
	Overall annoyance (L_{den} indicator)	Sleep disturbance (L_{night} indicator)
45 - 50	-	75000
50 - 55	-	65500
55 - 60	72600	33300
60 - 65	77400	9500
65 - 70	41600	500
70 - 75	10100	-
>= 75	400	-

- Development of new residential areas and construction of big business and commercial centers, most of them at the limits of the city, which generates modification in traffic composition and increases the traffic volume on specific routes, inducing in the same time agglomerations at the entrances and exits of the city.

The increase of urban traffic and noise was generated by the fast development of the urban area: increase of population density, enlarge of residential area and also of urban transportation network, development of new industrial and commercial centers which induced the rise of traffic for persons, goods and services, commuting and travels, change in inhabitants' mentality and habitudes concerning the use of public transportation facilities.

4. CASE STUDY FOR NOISE AND TRAFFIC EVOLUTION

The evolution of noise situation in the city of Cluj-Napoca was observed by the authors on several important streets, over a period of ten years (2001 - 2010). Only a small part of this study will be presented as follows, by using as reference a main street: Dorobantilor Street. It is an important road which tides the center of the city with the East exit. The examined noise source is the road traffic. During the time, a number of changes have occurred regarding the traffic characteristics and road pavement. It was designed for two-way traffic, with two bands per way, the pavement consisting of concrete slabs. Now the street has three traffic bands and parking spaces on both sides. Pedestrian area is separated from the road by a wall of green, consisting of bushes and trees, more than half of its length. The street traverses an area of the city with tall buildings, mostly apartment buildings. On about 80% of its length the traffic is unidirectional and mostly composed by light vehicles.

After some repairs, the road pavement was completely changed in 2009 with asphalt, on the section with unidirectional traffic. The street has eight pedestrian crossings, three of them with traffic lights (one automatic traffic action and two with manual control). Traffic speed is high; measurements have shown that it is one of the most traveled roads in the city, with the highest speeds, especially during night time. There are no speed restriction along the street and no slow systems. It also must be mentioned that only one public transportation bus-line has the route on the street in question. Currently traffic is composed mostly of light vehicles (Table 2). In the category of heavy vehicles, buses or coaches are present in the traffic and less vehicles for transportation of goods.

Figure 2 and table 2 present results of noise measurements made in 2001, respectively 2006 and 2010, in the same location, on Dorobantilor Street. Data from 2001 indicated a daily flow of 14105 vehicles, counted between the hours 6^{00} to 20^{00}, with a recorded maximum of 1772 vehicles per hour. Counts made in the years that followed allowed us to estimate the traffic for the same time-period of day to 21123 vehicles in 2006 (an average of 1616 veh./h at day, 1385 veh./h at evening and 346 veh./h at night) and respectively 29820 vehicles in 2010 (with he following average values: 2281 veh./h at day, 1955 veh./h at evening and 489 veh./h at night). Although the traffic has doubled during this period, the noise level dropped and was maintained within acceptable limits.

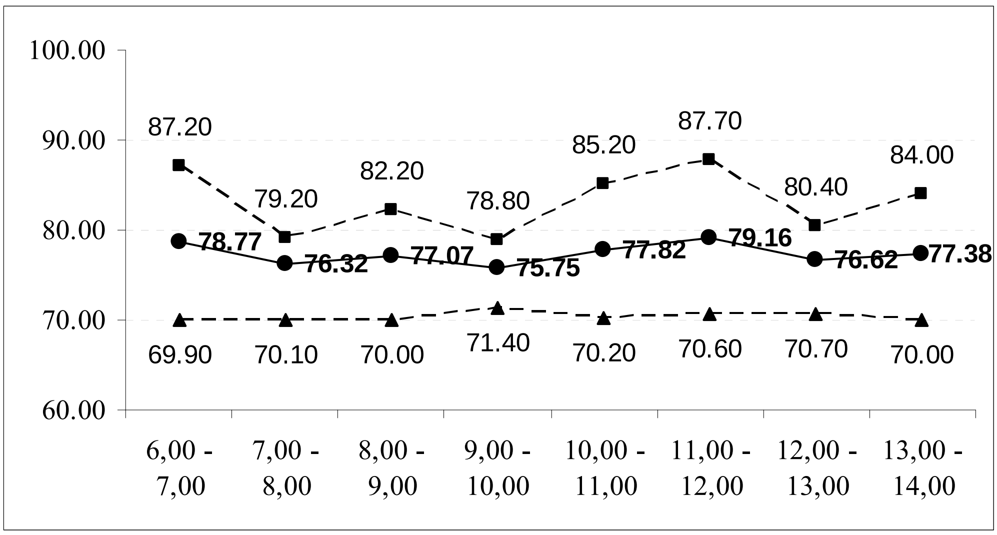

Figure 2. Noise measurements on Dorobantilor Street (year 2001): ▲ Lmin [dB], ● LAeq (1h) [dB], ■ Lmax [dB]
Daytime period: $6^{00} – 14^{00}$

Equivalent noise level decrease in 2006, compared to 2001, is primarily due to the decrease in the percentage of heavy vehicles in traffic, by reorganizing their routs through the city. The maintenance of equivalent noise levels in 2010, compared to 2006, even though traffic has increased, is due to the change of the entire road surface during the year 2009 and the decrease of traffic speed due to greater traffic.

To analyze the existing noise and in order to find possible methods to reduce noise exposure, the noise map of the region was developed, with the help of the dedicated software for noise map modeling, CadnaA. Although the noise situation in different areas of the city, for 2006, is reflected in the noise map of Cluj-Napoca, a detailed analysis of noise on a given street, namely the one analyzed by us, can not be done using only the images of the city map available to the public. The noise map of the city gives global information about the state of urban noise, aiming to evaluate the number of disturbed inhabitants, areas where maximum admissible levels of noise are exceeded and to highlight quiet areas. Any noise assessment on a specific road must be based on a sufficiently accurate noise model (depending on the intended purpose) which must be corrected using data obtained from field measurements.

A digital map was processed in AutoCAD software, by extracting the area of interest and dividing the existing information in different layers: noise source, road segments, dwelling buildings and parking spaces. Where it needed, the geometry of objects was created with closed or open polylines. New buildings were designed and positioned on the map with the help of ortho-photo images supplied by Google Earth. The DWG file was then converted to DXF and imported in CadnaA software (Fig. 3).

Table 2. Measurement results for traffic and noise on Dorobantilor Street (years 2006 and 2010)

Daytime periods for measurements	Measurement point Navodari Str. Year 2006			Measurement point Navodari Str. Year 2010		
	Nr. of light vehicles / h	Nr. of heavy vehicles / h	LAeq [3h] dB	Nr. of light vehicles / h	Nr. of heavy vehicles / h	LAeq [3h] dB
$7^{00} – 11^{00}$	1533	77	72,36	2153	13	71,19
$11^{00} – 15^{00}$	1597	40	71,85	2267	13	72,59
$15^{00} – 19^{00}$	1583	18	72,17	2385	13	72,84

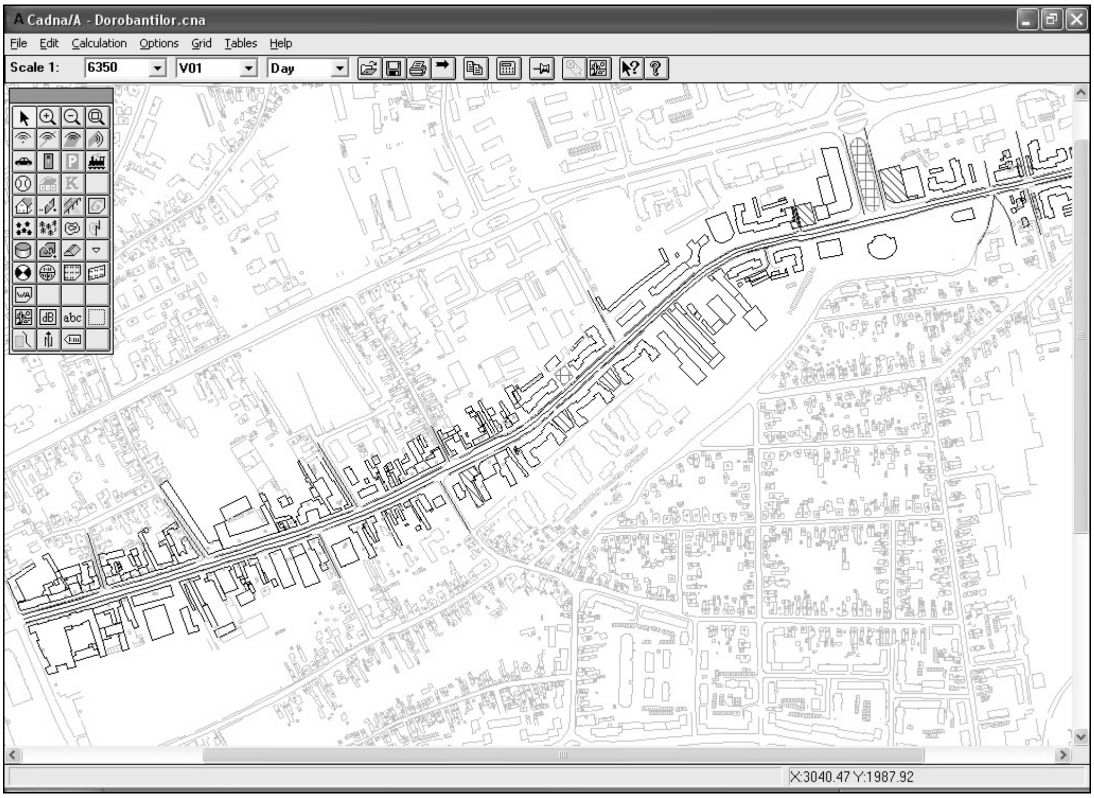

Figure 3. Digital map of a delimitated area, imported in CadnaA software

Besides the geometrical properties of the objects (position, height, shape), included in the thematic map of the area, the noise mapping software needs some other input data in order to calculate the model: data related to the road traffic (number, type and velocity of vehicles, traffic type), type of the road surface, absorption coefficients, meteorological data, demographic data. The input data was considered according to the guidelines given by The Guide regarding the interim calculation methods of noise indicators for the noise made by activities from industrial areas, road, railway and aerial traffic beside airports, 2006, for mapping agglomerations. The calculation method was NMPB-Routes-96, the interim method for road traffic noise. The calculation was made in the emission sites, using a grid cell of 10mp and 4m height. Noise levels were described in terms of L_{den} and L_{night} as required indices by the environmental noise directive 2002/49/EC (Figures 4 & 5).

Data related to the traffic for every street segment of the considered area were estimated based on the existing database of traffic measurements (Popescu, 2007), by extracting the measurements points situated on Dorobantilor Street and adjacent streets. Because the traffic measurements were made during the day time, they were used to estimate the total traffic volume during 24 hours, considering that 70% of this is traffic of the day (7^{00} to 19^{00}), 20% traffic of the evening (19^{00} to 23^{00}) and 10% traffic of the night period (23^{00} to 7^{00}).

The noise map indicated that the admissible levels for L_{den} (70 dB) and L_{night} (60 dB) indicators, established by Romanian legislation (Table 3), are overlapped on the entire length of the street. Considering that the values of these indicators need to drop for the year 2012 with 5dB, several scenarios for noise prediction were modeled, by reducing traffic, reducing speed of the vehicles or changing the road surface (Table 4).

A receiver was placed on the noise map (Fig. 5), in the position where noise measurements were made (Table 2). In table 4 were indicated noise levels obtained in this point by computer simulation with CadnaA software. By modifying the input data, we aimed to establish conditions for obtaining equivalent noise levels as close to those required by law, both for L_{den} and L_{night}. Following observations were made (Table 4):

- At the speed of 50 km/h, which is the maximum authorized vehicles speed on this street, L_{den} is over 70 dB, thus the limitation of speed to 40 km/h is imposed.

- By eliminating heavy vehicles from traffic and keeping the speed at 40 km/h, we obtain a reduction of 3 dB for L_{den} and 3.1 dB for L_{night}, thus obtaining noise values closed to the limits imposed by legislation.

Table 3 Noise limitations for L_{den} and L_{night} indicators, for action planning

Noise sources	L_{den} [dB]		L_{night} [dB]	
	Maximum values – to be reached for 2012	Admissible maximum levels	Maximum values – to be reached for 2012	Admissible maximum levels
Road traffic	65	70	55	60

Table 4 Noise at the receiver, obtained by computer simulation with CadnaA software.

Nr. of vehicles/h			Heavy veh. [%]	Speed [km/h]		Receiver	Sound spectrum [dB]					
Day	Evening	Night		Light veh.	Heavy veh.	L_{den} [dB] / L_{night} [dB]	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1616	1385	346	2,78	40	30	73,0	59,0	63,0	66,1	69,0	65,9	60,4
						63,9	49,8	53,8	57,0	59,9	56,8	51,3
			-	40	-	70,0	56,0	60,0	63,1	66,0	62,9	57,4
						60,8	46,8	50,8	53,9	56,9	53,8	48,3
			-	50	-	71,2	57,2	61,2	64,3	67,3	64,2	58,7
						62,1	48,0	52,1	55,2	58,2	55,0	49,5
1293	1108	277	-	40	-	69,0	55,0	59,0	62,1	65,0	61,9	56,4
						59,9	45,8	49,8	53,0	55,9	52,8	47,3
970	831	208	-	40	-	67,7	53,7	57,8	60,9	63,8	60,7	55,2
						58,6	44,6	48,6	51,7	54,7	51,5	46,0
646	554	138	-	40	-	66,0	52,0	56,0	59,1	62,0	58,9	53,4
						56,8	42,8	46,8	49,9	52,9	49,8	44,3
By changing the road surface from smooth asphalt to porous surface:												
646	554	138	-	40	-	65,0	51,0	55,0	58,1	61,0	57,9	52,4
						55,8	41,8	45,8	48,9	51,9	48,8	43,8

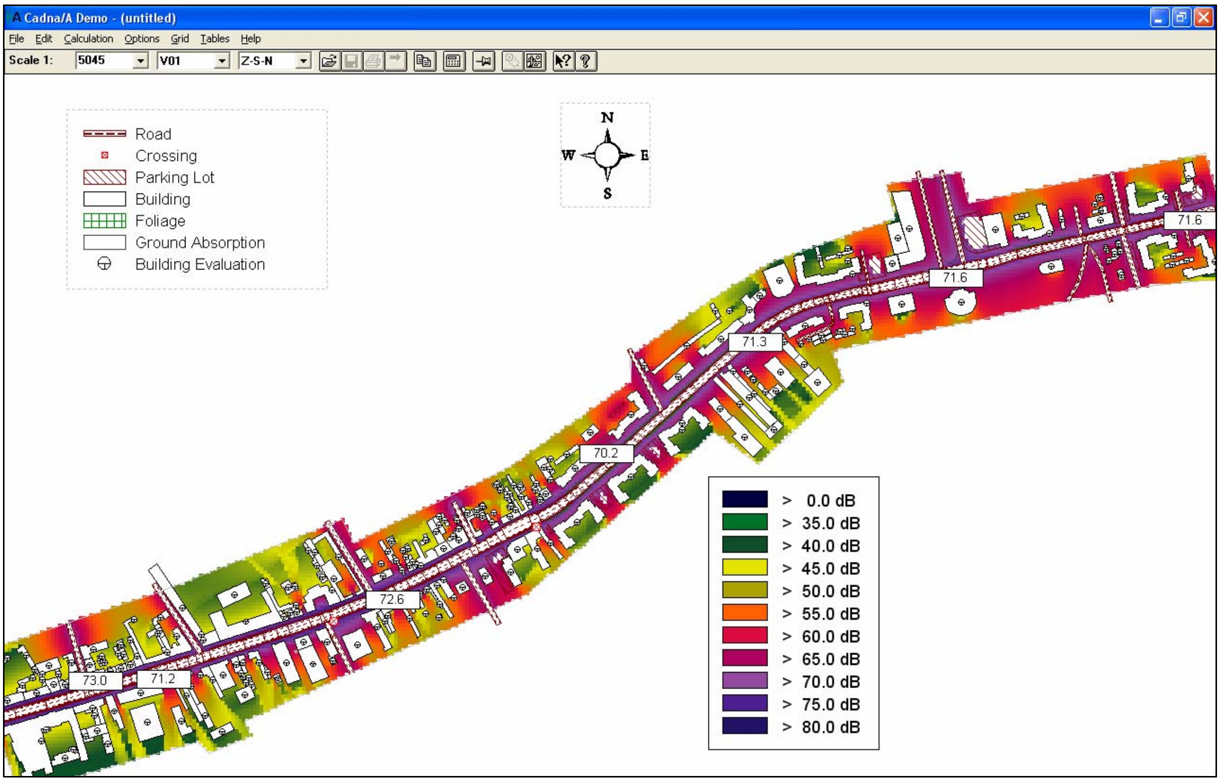

Figure 4. Noise emitted from road traffic on Dorobantilor Street Cluj-Napoca. CadnaA software; L_{den} map

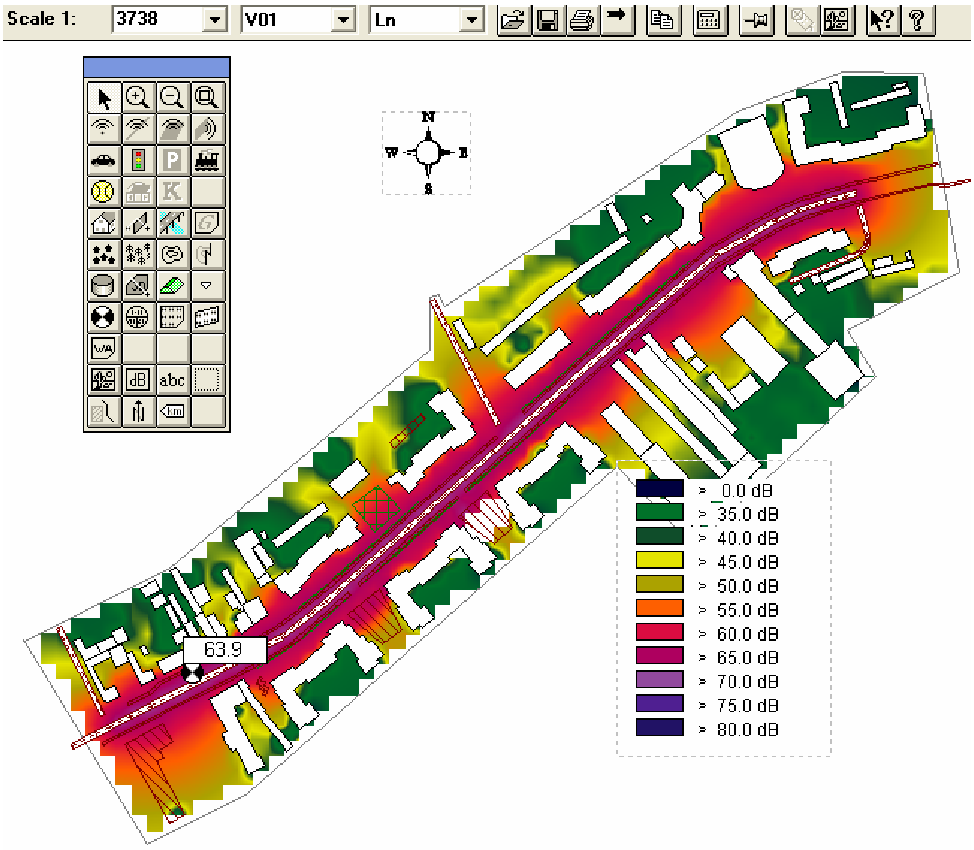

Figure 5. Noise emitted from road traffic on Dorobantilor Street Cluj-Napoca
CadnaA software; L_{night} map – detail, with the position of receiver

- The reduction of vehicles speed under 40 dB, at the same traffic, does not significantly reduce the noise.

- To achieve noise reduction at the target limits to be reached in 2012 (Table 3), we have examined alternative traffic reduction to 80%, 60% and respectively 40% of baseline. Assumptions for heavy vehicles traffic restriction and speed restriction of 40 km/h have been maintained. As result, we have obtained the reduction up to 4 dB for both L_{den} and L_{night}.

- Further reduction to 65 dB for L_{den} may be achieved by changing the road surface from smooth asphalt to porous surface. However, even under these conditions, the noise exceeds 55 dB during the night-time.

5. CONCLUSIONS

The assessment made at the level of the entire area of Cluj-Napoca city has released that the legal accepted maximum levels of noise are exceeded on almost all main streets and specific measures have to be establish in order to remedy this situation. Solutions to be applied are harder to find in the current situation: the traffic on these roads is almost impossible to be reduced, but rather it is growing, and noise limits imposed by legislation will be more restrictive in 2012, both for L_{den} and L_{night}.

The noise evolution study presented for Dorobantilor Street shows a situation in which the noise was reduced and then maintained in the condition of double traffic, due to the measures taken by the municipality to redirect the heavy traffic in the city and renew the road asphalt. Moreover, the conditions have changed: traffic growth has resulted in reducing traffic speed, due to the limited capacity of the street and increasing the number of cars parked on the side.

Measures for noise reduction should be adapted to any specific situation. A general observation is that, because of the growing number of vehicles, the alternative of traffic reduction will become increasingly difficult to enforce. Solution under these conditions is to act on the transmission path and receiver. Perhaps in the future the problem will be addressed in terms of noise absorbing properties of every material around us and new protection methods for the receiver, as a group or individually. Similar to assess the daily dose of noise exposure for working environments, calculation and measurements will be done for the overall daily dose exposure assessments in everyday life.

It is estimated that the study provides information that may be valuable for future research related to urban noise, to noise mitigation plans on different scenarios and also provides a basis for achieving noise maps in the next action of 2012.

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