ICSV14
Cairns • Australia
9-12 July, 2007

MANAGEMENT OF ENVIRONMENTAL NOISE – CRACOW EXAMPLE

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Abstract

The article shows an acoustic climate control system on the example of the City of Cracow. Information layers made in the SoundPlan, INM application, MapInfo and GRASS software are the system core.
These layers show maps, which characterise noise emitted from individual sources (traffic-related noise - road, railway and air, and industrial and communal noise), and maps of areas exposed to noise and areas with exceeded acceptable values. The layers have been made pursuant to valid legal acts.
Designed and built acoustic climate monitoring system and results of round-the-clock measurements carried out in order to assess an acoustic climate in Cracow conurbation were presented in the second part of this article.
Among other things, the designed and completed monitoring system has been used for the purpose of railway and road acoustic climate round-the-clock monitoring.
The system consisted of: an acoustic monitoring station, measuring system for weather conditions, GPS device, and audio and video signal recording device.The results of testing so obtained have served to build databases for the rail and road traffic for the Capital-Royal City of Cracow.
The results of this report constitute a separate module in the form of information layers of the acoustic climate management system for the Capital-Royal City of Cracow, but due to their universal character, they may also be used for building management systems in other cities, agglomerations, municipalities, etc.
The spatial information system technology (GIS) was used to create the system. Two application programs were designed and developed, which allow for work in public data communications networks and locally, independently of hardware platform and operating system.
In future, the designed and systematically developed system for city acoustic climate management will become an integral element of city management system.
It will allow for very convenient and extremely quick making of decisions related to acoustic climate.

1. INTRODUCTION

The battle against environmental noise pollution has been fought for many years now. In spite of some achievements in this field, it was impossible to make cities silent and quiet, which would ensure full comfort of life. Existing trends shows that the situation is systematically getting worse.

In order to counteract there is whole range of tasks taken on, from responding to noise-related complaints to making acoustic maps, from incidental measurements and continuous monitoring to actions aimed to reduce noise and to determine areas at particular risk. We may distinguish here three major approaches:

- ***Separate approach (conventional),***

  separate solution is being found for each problem;

- ***Combined approach***

  each problem has its own solution, but data may be exchanged, and accepted methods reused; example: use of data obtained from noise monitoring system for control and information purposes (primary objective) and for acoustic map update (additional objective);

- ***Integrated approach***

  system solution, in which data obtained from various sources would be collected and archived in a database (with tight or dispersed structure), and after processing, used for various purposes; thus it is possible to achieve better efficiency and rational management of resources. Response to complaints, noise map, noise monitoring, noise forecasting and reduction, may be executed on the grounds of the same, once obtained data.

In the scope of the above-mentioned special grant, in this study has been designed and continuously develop an integrated noise management system for the City of Cracow.

The city occupies an area of 326,8 km2. The developed lands (residential settlement areas and other) occupy approx. 30% of the city area, and approx. 9% is occupied by communication areas, whereas the croplands occupy as much as approx. 51%.

The population of the city is approx. 750 thousand - average population density is approx. 2290 of residents per 1 km2. The residents of Cracow make approx. 1,9% of the whole population of Poland and 23% of residents of the Małopolska province. The population of Cracow was growing systematically until 1990.

Besides all these elements - Cracow belongs to the most "acoustically affected" towns in Poland.

In order to discuss in more details the designed acoustic climate management system and models, which provided the basis for its development, let’s first answer the questions: what is acoustic climate and which elements affect it ?

2. ACOUSTICS CLIMATE MODEL

We may say that acoustic climate is a combination of phenomena occurring in environment, and caused by noise sources existing in that environment or beyond of it. As a result, are may speak about natural acoustic climate (noise sources are related to natural processes and behaviours of living beings in that environment: sea swoosh, tree swoosh, singing of birds), and man-made acoustic climate.

In general, environment acoustic climate will mean a combination of partial phenomena occurring in environment and described by the equation (1).

$$K_A = f(K_1, K_2, K_3, ..., K_N) \tag{1}$$

where: K_A – acoustic climate,

$K_1, K_2, K_3, ..., K_N$ – partial acoustic climates.

Partial acoustic climate refers to type of noise polluting the environment, such as : road, railway, industrial, high voltage line, communal, etc. Each of these partial climates is characterised by values describing noise related to a particular partial climate.
In order to evaluate population exposure to noise, it is necessary to make use of exceeded threshold and acceptable noise levels during the daytime and at night. Regulation of the Minister of Environment issued on October 14, 2002 (Journal of Laws - Dz.U.02.179.1498) provides a precise tool that helps to evaluate population exposure to noise. M_i index value shall decide about the order of actions related to protection from noise. Noise exposure index (2) was determined as follows:

$$M_i = 0.1 m_i \left(10^{0.1 \Delta L_i} - 1\right) \tag{2}$$

where: M_i – index value, ΔL_i – value of exceeded acceptable noise level [dB],
m_i – number of people located in an area with exceeded acceptable noise level.

When with $\Delta L_i \leq 0$ the M index value is 0.

Consequently, we introduce acoustic climate index (3).

$$K_{A\_i} = \frac{M_i}{M_{DOPi}} \tag{3}$$

where: M_i – value of noise exposure index, for particular type of noise in a given point,
M_{DOPi} – maximum value of noise exposure index, which occurs at noise level equal to threshold level.

Partial acoustic climate may be characterized by K_{A_i} ranging from 0 to 1. Climate is deemed acceptable for $K_{A\_i} = 0$, and unacceptable for value $K_{A\_i} = 1$.

Most important noise types in contemporary cities are as follows:

road,railway,industrial,air, communal, high voltage line.

Assuming that acceptable values of K_{A_i} may be exceeded both in daytime and at night, we receive a collective measure, which characterises acoustic climate as a sum of indexes determined according to the following relation (4).

$$K_A = \sum_{i=0}^{6} (K_{A\_ROAD}, K_{A\_RAIL}, K_{A\_INDUS}, K_{A\_AIR}, K_{A\_COMM}, K_{A\_HVL}) \tag{4}$$

Thus calculated index K_A may range from 0 to 6, where the higher value of this index, the worse acoustic climate (more types of noise affect inhabitants). We may call this index a total analytical model of acoustic climate.

Acoustic climate may be characterised not only using analytical methods, but with a numeric model as well. In this study many analyses and noise map of Cracow have been done [2-4].

3. ACOUSTIC CLIMATE MONITORING SYSTEM

This part of work describes the acoustic climate monitoring system designed and built as part of a target project. This system includes two main subsystems: stationary and mobile. The first one consists of a server with software allowing to receive and acquire data.
Mobile system consists of a PC, GPS device (GPS60CSx) from Garmin and precise sound level meter (Svan 945A) from Svantek. The main component of this subsystem is software allowing to communicate with the above-mentioned equipment, and to acquire data in form of preset data packages, and send it via wire or wireless transmission to stationary section of the monitoring system.

Among other things, the designed and completed monitoring system has been used for the purpose of railway and road acoustic climate round-the-clock monitoring.

The system consisted of: an acoustic monitoring station, measuring system for weather conditions, GPS device, and audio and video signal recording device – digital camera from Konica-Minolta allowing round-the-clock road and railway traffic registration.

The monitoring system was placed in various points in the City of Krakow. Railway noise has been measured in 10 points and road noise has been measured in 24 points in the City. Road noise monitoring points have been located at the distance of 10 metres from road edge, while railway noise monitoring points - 25 metres from road. In both of these cases the measuring microphone was installed at the height of 4 metres. Tables 1 and 2 shows the results of round-the-clock noise monitoring in form of an equivalent course of noise level (A - L_{Aeq}), and L_{Amin} and L_{Amax} values recorded every 1 second.

Precise locations of these points have been determined with accuracy of 3 to 5 metres, using the GPS60CSx device. Coordinates of monitoring points are compiled in Tables 1 and 2. The number of monitoring points for railway acoustic climate has been selected so as to take into account all main railway routes crossing Cracow conurbation. Road monitoring points have covered all road categories.

Non-acoustic parameters have been monitored besides acoustic parameters, including: traffic volume divided into quantity of heavy and light vehicles, weather conditions, temperature, wind velocity, possible precipitation, etc.

A series of noise measurements (almost one thousand) for road, railway, industrial and aircraft noise have been carried out in an effort to combine monitoring model with monitoring carried out by policing service.

Some very detailed assessments of acoustic climate have been carried out as part of this task, among other things including:

- assessment of aircraft noise impact on Cracow conurbation;
- assessment regarding the impact of municipal transport services operated by MPK Cracow (Municipal Transport Authority), including both road and rail transport;
- completed industrial noise impact assessment for Mittal Steel Poland S.A. – Cracow Branch.

The outcome of the above-mentioned assessments includes huge resource databases kept at the Department of Mechanics and Vibroacoustics AGH-UST in Cracow. They provide the basis to carry out detailed acoustic climate analysis and to take measures aimed to improve it not only in Cracow, but also in other areas of this sort, cities, conurbations, etc.

Currently, designed and completed Integrated Acoustic Climate Management System is being implemented by Royal Capital City of Cracow. We should emphasize that it will be possible to make use of the results obtained when carrying out this project in other conurbations, cities, municipalities, etc.

Even today there is possibility for the designed and systematically developed Integrated Acoustic Climate Management System for the City to become an integral part of general

conurbation management system. It allows very comfortable and quick decision making as regards issues related to acoustic climate.

Table 1. Monitoring Measurement for Railway Acoustic Climate.

No	Date	Equivalent noise level L_{Aeq}		Fast Train	Slow Train	Goods Train	Other	No GPS	Point GPS	Route Location
1	29.04.06r	L_{AeqD} [dB]	64.6	33	44	31	32	35	N50 05.005 E19 53.124	Kraków-Katowice
		L_{AeqN} [dB]	62.3	9	5	17	5			
2	02.05.06r	L_{AeqD} [dB]	53.4	-	-	-	21	33	N50 00.376 E20 02.074	Kraków – Wieliczka Ul.Zolla
		L_{AeqN} [dB]	46.8	-	-	-	5			
3	03.05.06r	L_{AeqD} [dB]	64.8	42	26	12	12	30	N50 06.276 E19 59.167	Kraków - Warszawa
		L_{AeqN} [dB]	63.3	7	2	5	1			
4	08.05.06	L_{AeqD} [dB]	61.0	-	38	9	14	44	N49 59.148 E19 52.894	Kraków - Zakopane
		L_{AeqN} [dB]	63.3	2	9	8	5			
5	12.05.06	L_{AeqD} [dB]	65.7	30	32	35	15	34	N50 01.072 E20 03.620	Kraków - Tarnów
		L_{AeqN} [dB]	62.4	7	6	14	4			
6	15.05.06	L_{AeqD} [dB]	53.8	-	2	17	3	31	N50 04.611 E19 49.534	Łazowa
		L_{AeqN} [dB]	55.4	-	-	8	-			
7	19.05.06	L_{AeqD} [dB]	54.4	-	-	12	2	26	N50 04.273 E20 10.227	Czeczeńska
		L_{AeqN} [dB]	56.3	-	-	3	3			
8	23.05.06	L_{AeqD} [dB]	59.9	-	-	4	-	29	N50 05.579 E19 54.758	Stelmachów
		L_{AeqN} [dB]	56.4	-	-	3	-			
9	18.05.06	L_{AeqD} [dB]	59.8			39	14	32	N50 04.237 E19 58.490	Obejście Wschodnie Krakowa Gł.
		L_{AeqN} [dB]	56.1			19	4			
10	29.05.06	L_{AeqD} [dB]	60.5	-	-	9	57	36	N50 04.611 E19 49.534	Kraków Gł. - Balice
		L_{AeqN} [dB]	48.5	-	-	-	9			

Table 2. Monitoring Measurement for Road Acoustic Climate.

No	Date	Equivalent noise level L_{Aeq}		Vehic. Car [car/h]	Vehic. Track [tra/h]	No. GPS	Point GPS	Location
1	31.05. 06	L_{AeqD} [dB]	74.9	1381	294	45	N49 59.509 E19 52.664	Obwodnica A4 Odcinek Balice -Opatkowice
		L_{AeqN} [dB]	70.4	393	172			
2	01.06. 06	L_{AeqD} [dB]	72.6	3240	293	48	N50 05.270 E19 53.767	Ul.Conrada
		L_{AeqN} [dB]	68.9	606	93			
3	05.06. 06	L_{AeqD} [dB]	71.7	869	221	47	N50 00.079 E20 00.091	Obwodnica A4 Odcinek Opatkowice-Wielicka
		L_{AeqN} [dB]	67.4	197	115			
4	06.06. 06	L_{AeqD} [dB]	66.0	887	81	49	N50 04.152 E19 54.654	Ul.Czarnowiejska
		L_{AeqN} [dB]	61.3	200	23			
5	08.06. 06	L_{AeqD} [dB]	70.7	1547	148	53	N50 00.728 E19 56.702	Ul.Myślenicka
		L_{AeqN} [dB]	64.6	262	23			
6	12.06. 06	L_{AeqD} [dB]	73.2	2150	204	41	N50 05.764 E19 52.358	Ul.Radzikowskiego
		L_{AeqN} [dB]	68.2	286	71			
7	13.06. 06	L_{AeqD} [dB]	72.4	2600	283	42	N50 05.169 E19 59.082	Ul.Bora Komorowskiego
		L_{AeqN} [dB]	68.0	419	81			
8	19.06. 06	L_{AeqD} [dB]	70.6	2479	158	50	N50 02.651 E19 56.101	Ul.M.Konopnickiej
		L_{AeqN} [dB]	66.5	578	39			
9	21.06. 06	L_{AeqD} [dB]	70.5	1128	115	40	N50 05.691 E19 53.564	Ul.Jasnogórska
		L_{AeqN} [dB]	65.0	227	46			
10	22.06. 06	L_{AeqD} [dB]	70.6	1022	124	43	N50 06.640 E19 57.943	Al.29 listopada
		L_{AeqN} [dB]	67.1	285	46			

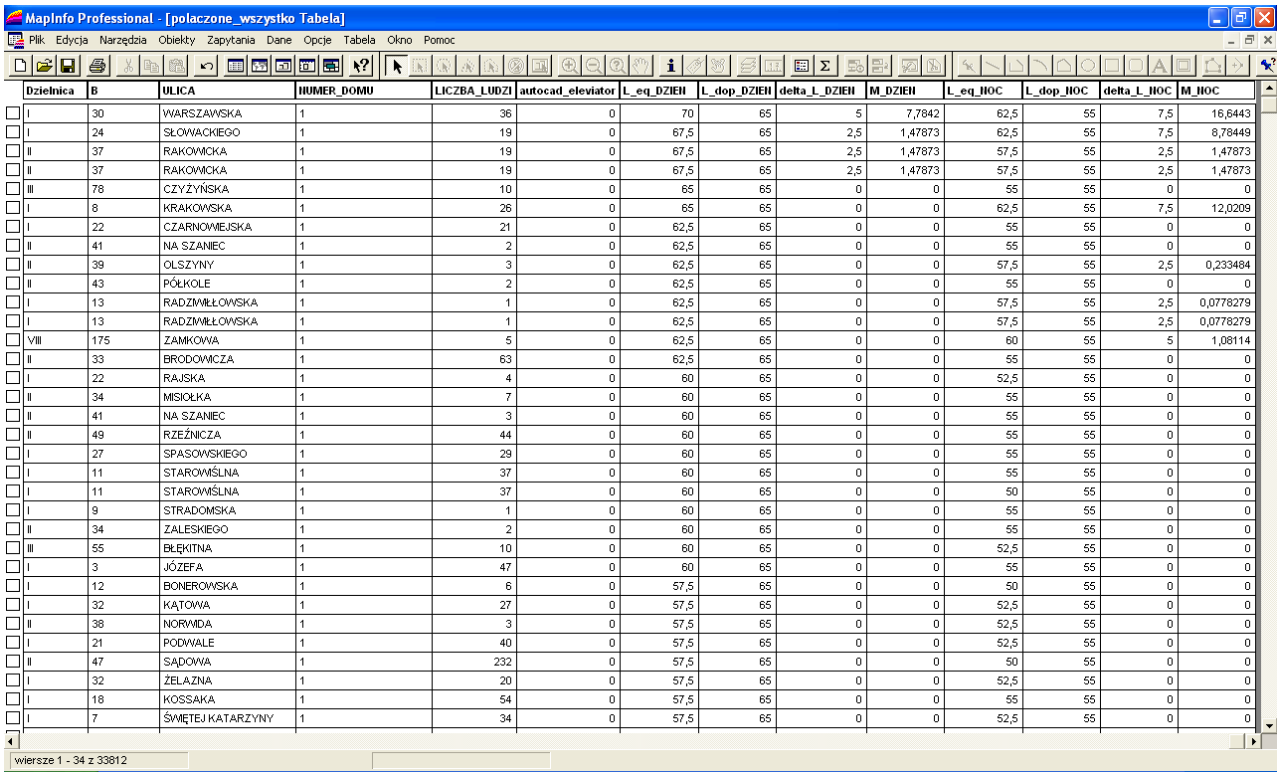
4. ACOUSTIC CLIMATE MANAGEMENT SYSTEM

The control system consists of technical and non-technical (legal and administrative) elements. Control is carried out by making administrative decisions [1,5-7].

In order to exercise acoustic climate control, we decided to use spatial information system technology (GIS), where phenomena that take place in environment are relatively easy to illustrate.

The M_i index values and other acoustic climate measures were determined for the city area, and then they were converted into form corresponding to some spatial information systems existing on the market.

An application has been developed, which allows to make environment data prepared in this way available through public data communications networks (Fig. 1).



Dzielnica	B	ULICA	HUMER_DOMU	LICZBA_LUDZI	autocad_eleviator	L_eq_DZIEN	L_dop_DZIEN	delta_L_DZIEN	M_DZIEN	L_eq_NOC	L_dop_NOC	delta_L_NOC	M_NOC
I	30	WARSZAWSKA	1	36	0	70	65	5	7,7842	62,5	55	7,5	16,6443
I	24	SŁOWACKIEGO	1	19	0	67,5	65	2,5	1,47873	62,5	55	7,5	8,78449
II	37	RAKOWICKA	1	19	0	67,5	65	2,5	1,47873	57,5	55	2,5	1,47873
II	37	RAKOWICKA	1	19	0	67,5	65	2,5	1,47873	57,5	55	2,5	1,47873
III	78	CZYŻYŃSKA	1	10	0	65	65	0	0	55	55	0	0
I	8	KRAKOWSKA	1	26	0	65	65	0	0	62,5	55	7,5	12,0209
I	22	CZARNOWIEJSKA	1	21	0	62,5	65	0	0	55	55	0	0
II	41	NA SZANIEC	1	2	0	62,5	65	0	0	55	55	0	0
II	39	OLSZYNY	1	3	0	62,5	65	0	0	57,5	55	2,5	0,233484
II	43	PÓŁKOLE	1	2	0	62,5	65	0	0	55	55	0	0
I	13	RADZIMIŁŁOWSKA	1	1	0	62,5	65	0	0	57,5	55	2,5	0,0778279
I	13	RADZIMIŁŁOWSKA	1	1	0	62,5	65	0	0	57,5	55	2,5	0,0778279
VIII	175	ZAMKOWA	1	5	0	62,5	65	0	0	60	55	5	1,08114
II	33	BRODOWICZA	1	63	0	62,5	65	0	0	55	55	0	0
I	22	RAJSKA	1	4	0	60	65	0	0	52,5	55	0	0
II	34	MISIOŁKA	1	7	0	60	65	0	0	55	55	0	0
II	41	NA SZANIEC	1	3	0	60	65	0	0	55	55	0	0
II	49	RZEŹNICZA	1	44	0	60	65	0	0	55	55	0	0
I	27	SPASOWSKIEGO	1	29	0	60	65	0	0	55	55	0	0
I	11	STAROWIŚLNA	1	37	0	60	65	0	0	55	55	0	0
I	11	STAROWIŚLNA	1	37	0	60	65	0	0	50	55	0	0
I	9	STRADOMSKA	1	1	0	60	65	0	0	55	55	0	0
II	34	ZALESKIEGO	1	2	0	60	65	0	0	55	55	0	0
III	55	BŁĘKITNA	1	10	0	60	65	0	0	52,5	55	0	0
I	3	JÓZEFA	1	47	0	60	65	0	0	55	55	0	0
I	12	BONEROWSKA	1	6	0	57,5	65	0	0	50	55	0	0
I	32	KĄTOWA	1	27	0	57,5	65	0	0	52,5	55	0	0
II	38	NORWIDA	1	3	0	57,5	65	0	0	52,5	55	0	0
I	21	PODWALE	1	40	0	57,5	65	0	0	52,5	55	0	0
II	47	SĄDOWA	1	232	0	57,5	65	0	0	50	55	0	0
I	32	ŻELAZNA	1	20	0	57,5	65	0	0	52,5	55	0	0
I	18	KOSSAKA	1	54	0	57,5	65	0	0	55	55	0	0
I	7	ŚWIĘTEJ KATARZYNY	1	34	0	57,5	65	0	0	52,5	55	0	0

Figure 1. Selected information from database of acoustic climate management system.

5. CONCLUSIONS

The paper shows an acoustic climate control system apllied for the City of Cracow. Information layers made in the SoundPlan, INM application, MapInfo and GRASS software are the system core.

Designed and built acoustic climate monitoring system and results of round-the-clock measurements carried out in order to assess an acoustic climate in Cracow conurbation were presented in the second part of this article. Among other things, the designed and completed monitoring system has been used for the purpose of railway and road acoustic climate round-the-clock monitoring.

These layers show maps, which characterise noise emitted from individual sources (traffic-related noise - road, railway and air, and industrial and communal noise), and maps of areas exposed to noise and areas with noise exceeded limits levels. The layers have been made pursuant to valid legal acts [8-13].

The spatial information system technology (GIS) was used to create the system. Two application programs were designed and developed, which allow for work in public data communications networks and locally, independently of hardware platform and operating

system.

In future, the designed and systematically developed system for city acoustic climate management will become an integral element of city management system.It will allow for very convenient and extremely quick making of decisions related to acoustic climate.

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