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# EVALUATION OF THE ENVIONMENTAL CAPACITY OF AN AIRPORT IN TERM OF NOISE

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*It is obvious that the increase of the traffic volume can be an attractive measure for an airport. However, the environmental problems associated with air transport, among which the most important are those related to noise and air pollution can generate constraints that impose the limitation of this growth. An important constraint regarding the increase of the aircraft traffic related to an airport is represented by the need to limit the imissions for the sensitive receivers (houses, schools, hospitals) existing in its vicinity*

*The compulsory compliance with the environmental legislation of the airport, mainly noise and gaseous pollutants, imposes a limitation of air traffic called Environmental Capacity ($C_{env}$). Based on results of strategic noise mapping that is carried out periodically, by calculation, according to [1], [2] and [3], the paper presents a simple way to approximate the Environmental Capacity - noise component, for the particular conditions of an airport.*

*By the simple way in which it can be used, the described method can be proposed for the superior valorization of the information obtained from the strategic noise mapping.*

**Keywords:** airport noise, noise map, airport traffic volume, capacity of an airport.

## 1. Introduction

In practice, increase of the traffic related to an airport can be realized by respecting some limits. In literature [4], [5], [6], the concept of *environmental capacity of an airport* is used and it describes the growth limitations imposed on the activity of an airport in order to comply with the legislation regarding the environmental status of its vicinity.

The more general approach as described in *E. Konovalova*, Environmental Capacity of an airport as an element of balanced approach to aircraft noise

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control, Science & Military, 2010 [6], uses the concept of an airport capacity defined as the minimum of three capacities:

$C = \min(C_{op}; C_{ec}; C_{env})$, where:

$C_{op}$ is the operational capacity of an airport which is given by the available facilities of the airport (runway, taxiways, slots, terminal capacity)

$C_{ec}$ is the economic capacity, meaning the maximum flow of passengers or aircraft that can transit the airport under the given conditions;

$C_{env}$ is the environmental capacity of an airport meaning the maximum air traffic for which the environmental legislation is not violated.

The strategic noise mapping in the vicinity of an airport is an activity that is carried out with a certain periodicity (at intervals of maximum 5 years). If the descriptive parameters of the noise in the vicinity of the most exposed sensitive receivers are below the limits imposed by the legislation [7], the estimation of the admissible increase of the airport activities can be made by simple calculus, according to the exemple in the article. The adoption of reduction measures in accordance with the "balanced approach" as described in [8] and [9] and as imposed by [10], increases the environmental capacity of the airport, achieving a limit of higher traffic.

A consequence of the development of air transport is the increase in noise exposure of the population belonging to urban communities located in the vicinity of an airport.

The dose-effect studies show that at the same exposure of the population, the noise generated by air transport is more disturbing than the noise generated by road transport or rail transport.

Near many airports within the European Community, including Romania, there are inhabited areas exposed to the noise generated by the air traffic. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise sets out the necessary activities to be carried out in order to ensure sound environmental conditions in terms of noise.

Based on information contained in the strategic noise mapping for the airport, this article describes a way to evaluate the $C_{env}$, noise component.

For year 2016, the activity carried out at Bucharest “Baneasa” International Airport has been characterized by a relatively low traffic volume. The noise mapping has been performed based on the airplane noise calculation method ECAC.CEAC Doc. 29 [3], [11] using the segmentation technique mentioned in [3], section 7.5.

The strategic noise mapping carried out for the reference year 2016 within to comply the obligations imposed by Government Decision no. 321/2005 did not reveal noise index values beyond the permissible limits established by environmental legislation [5].

An increase in traffic volume makes more efficient use of the airport. However, the increase of traffic volume leads to the increase of noise levels across the airport's inhabited vicinity areas.

The noise levels generated by the airport activity and their distribution in the areas near the airport depend on the number of aircraft movements (landings and take-offs), the traffic structure (e.g. weight of the different noise groups) and the traffic distribution over the three periods of a day. The referenced periods of the day are *day* – time interval 7.00 - 19.00, *evening* - time interval 19.00 - 23.00, *night* - time interval 23.00 - 7.00. In addition, the meteorological conditions characteristic of the area, especially the wind, influence the direction of the operations and implicitly the distribution of the noise levels.

Except landings and take-offs, the study does not take into account the following airport-specific noise sources: taxiing of aircraft, APU operations, engine test stands, trucks, buses, heating-cooling devices. It also considers two variants of traffic:

- airport traffic corresponding to the reference year 2016;
- hypothetical increase of the traffic volume up to the limit level imposed by Order no. 152/558/1119/532–2008 [7], from environmental protection perspective.

## 2. Specific aspects of airport noise calculation

In case of air traffic noise calculation, the emission noise is calculated using larger grids, the points being spaced at 50-100 m, unlike the noise mapping of road and rail traffic, or the noise generated by industrial activity, where the noise emission is calculated in detail for all sensitive receivers using grids of up to 10 m.

An aircraft of a certain type generates different noise levels depending on the type of equipped engines. Therefore, in calculating of aircraft noise levels it is very important the availability of the real used aircraft type data.

### Grouping of aircraft types

To limit the diversity of the aircraft types to be included in the calculation, several types of airplanes are included in a group with similar characteristics, based on the following features: type of aircraft propulsion (jet, fan, or turbo-prop), number of engines (1, 2, 3, or 4), by-pass ratio for fan engines, MTOM - Maximum Take Off Mass (in kg). The most relevant parameter is MTOM, for which the following categories are defined as:

- General Aviation (GA): 5,700;

- Light aircraft: 5,700 - 10,000;
- Medium aircraft: 10,000 - 50,000;
- Heavy aircraft: 50,000 - 200,000;
- Very heavy aircraft: 200,000 - 400,000;
- Ultra heavy aircraft: > 400,000.

**Segmentation**

The working technique in calculating noise levels is the segmentation method. The flight path is divided into segments characterized by location, aircraft speed and power setting. The sound exposure level is calculated for each segment, corrected for the segment's finite length, then sums up the exposure levels for all segments at each point in the calculation grid [3],[11].

The definition of noise indicators $L_{den}$ (day-evening-night) and $L_n$ (night) are presented into the following formula [8]:

$$L_{den} = 10 \cdot lg\left[\left(\frac{1}{24}\right) \cdot \left(12 \cdot 10^{L_{day}/10} + 4 \cdot 10^{L_{evening}+5/10} + 8 \cdot 10^{L_{night}+10/10}\right)\right] \qquad (1)$$

where:

- $L_{day}$ [dB(A)] is daytime noise indicator;
- $L_{evening}$ [dB(A)] is evening noise indicator;
- $L_{night}$[dB(A)] is night-time noise indicator.

The equivalent continuous sound level and sound exposure level are defined as:

$L_{eq,T} = 10\lg \frac{1}{T}\int_0^T \left(\frac{p^2(t)}{p_0^2}\right) dt$, where:

$p(t)$ is A-weighted instantaneous acoustic pressure;

$p_0$ is the reference acoustic pressure (20 μPa)

T is total measurement time.

$L_{AE} = 10\lg \frac{1}{\tau_0}\int_0^T \left(\frac{p^2(t)}{p_0^2}\right) dt$, where

$p(t)$ is A-weighted instantaneous acoustic pressure;

$p_0$ is the reference acoustic pressure (20 μPa)

$\tau_0$ is the reference time (1 s).

From the above relations the connection between $L_{eq,T}$ and $L_{AE}$ - Relation (2)

$$L_{eq,T} = L_{AE} + 10\lg\left(\frac{\tau_0}{T}\right)$$

The logarithmic summation of all the acoustic events from a reference period of contributions in one point, considering one day as example, for each trajectory segment (i) and for each aircraft group (j), is made using relation (3), which is the general form of the equation (2).

**Adapting the above-mentioned indices for aircraft noise**

The relation between the acoustic exposure level $L_{AE}$ and the equivalent continuous sound pressure level $L_{eq}$ corresponding to a time interval T is:

$$L_{eq} = L_{AE} + 10 \cdot lg\left(\frac{\tau_0}{T}\right) \tag{2}$$

where:

$\tau_0 = 1s$

The parameters are defined through the relations $L_d\,(L_{day}), L_e\,(L_{evening}),\ L_n\,(L_{night})$ at a point.

$$L_d = 10 \cdot lg\left(\frac{\tau_0}{T_d} \cdot \sum_{i,j} N_{d,i,j} \cdot 10^{\frac{L_{AE,i,j}}{10}}\right) \tag{3}$$

$$L_e = 10 \cdot lg\left(\frac{\tau_0}{T_e} \cdot \sum_{i,j} N_{e,i,j} \cdot 10^{\frac{L_{AE,i,j}}{10}}\right) \tag{4}$$

$$L_n = 10 \cdot lg\left(\frac{\tau_0}{T_n} \cdot \sum_{i,j} N_{n,i,j} \cdot 10^{\frac{L_{AE,i,j}}{10}}\right) \tag{5}$$

$$L_{den} = 10 \cdot lg\left[\left(\frac{1}{T_{den}}\right) \cdot \left(T_d \cdot 10^{\frac{10 \cdot lg\left(\frac{\tau_0}{T_d} \cdot \sum_{i,j} N_{d,i,j} \cdot 10^{\frac{L_{AE,i,j}}{10}}\right)}{10}} + T_e \cdot 10^{\frac{10 \cdot lg\left(\frac{\tau_0}{T_e} \cdot \sum_{i,j} N_{e,i,j} \cdot 10^{\frac{L_{AEi,j}}{10}}\right)+5}{10}} + T_n \cdot 10^{\frac{10 \cdot lg\left(\frac{\tau_0}{T_n} \cdot \sum_{i,j} N_{n,i,j} \cdot 10^{\frac{L_{AEi,j}}{10}}\right)+10}{10}}\right)\right]$$

$$L_{den}=10\cdot lg\left[\left(\frac{1}{T_{den}}\right)\cdot\left(12\cdot\left(\frac{\tau_0}{T_d}\cdot\sum_{i,j}N_{d,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}\right)+4\cdot\left(\frac{\tau_0}{T_d}\cdot\sum_{i,j}N_{d,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}\right)\cdot 10^{\frac{5}{10}}+8\cdot\left(\frac{\tau_0}{T_d}\cdot\sum_{i,j}N_{d,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}\right)\cdot 10^{\frac{10}{10}}\right)\right]$$

$$L_{den}=10\cdot lg\left[\left(\frac{\tau_0}{T_{den}}\right)\cdot\left(T_d\cdot\left(\frac{\tau_0}{T_d}\cdot\sum_{i,j}N_{d,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}\right)+T_e\cdot\left(\frac{\tau_0}{T_d}\cdot\sum_{i,j}N_{d,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}\right)\cdot 10^{\frac{5}{10}}+T_n\cdot\left(\frac{\tau_0}{T_d}\cdot\sum_{i,j}N_{d,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}\right)\cdot 10^{\frac{10}{10}}\right)\right]$$

Finally, it results:

$$L_{den}=10\cdot lg\left[\left(\frac{\tau_0}{T_{den}}\right)\cdot\left(\sum_{i,j}N_{d,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}+3{,}16\cdot\sum_{i,j}N_{e,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}+10\cdot\sum_{i,j}N_{n,i,j}\cdot 10^{\frac{L_{AE\,i,j}}{10}}\right)\right] \tag{6}$$

or:

$$L_{den}=10\cdot lg\left[\left(\frac{\tau_0}{T_{den}}\right)\cdot\sum_{i,j}\left(N_{d,i,j}+3{,}16\cdot N_{e,i,j}+10\cdot N_{n,i,j}\right)\cdot 10^{\frac{L_{AE\,i,j}}{10}}\right] \tag{7}$$

where:

- $T_{den}$ is duration of day + evening + night (24 h = 86400 s);
- $T_d$ is the duration of day (12 h = 43200 s)
- $T_e$ is the duration of evening (4 h = 14400 s)
- $T_n$ is the duration of night (8 h = 28800 s)
- $\tau_0 = 1s$;
- $N_d, N_e, N_n$ are the number of movements during one day (12 h), one evening (4 h) and one night (8 h), respectively;
- *i* and *j* are the flight track index and group index, respectively.

The sound exposure in a specific point is defined accordingly to the formula [8]:

$$L_{AE}(x,y)=L_{A,\max}(\xi,d)+\Lambda(\beta,l)+\Delta_L+\Delta_V+\Delta_F \tag{8}$$

where:

- $L_{AE}(x,y)$ is the sound exposure level from a selected point (coordinates x,y) produced by a movement on *take-off* or *approach* with thrust $\xi$ at the shortest distance to the flight *d*, with speed *v*;

- $L_{A,\max}(\xi, d)$ is the maximum sound level from noise-power-distance curve for thrust $\xi$ and distance *d*;
- $\Lambda(\beta, l)$- correction for extra attenuation of sound during propagation lateral to the direction of airplane, for horizontal lateral distance *l* and elevation angle $\beta$;
- $\Delta_L$ correction for directivity behind the start of take-off ground roll;
- $\Delta_V$ correction for duration allowance depending on the speed *v*;
- $\Delta_F$ correction for finite length of segment of the flight path.

### 3. An analysis of the situation in the year 2016

Table 1 represents the available data obtained from the airport administration representing the lists of aircraft that landed and took off during the whole year with the days and times in which these operations took place. The data is organized on noise groups, distribution, landing / take-off direction and time distribution on the three characteristic intervals of the day.

*Table 1*

**Emission data used, including aircraft movements organized according to the appropriate noise groups.**

| Period | Operation | Runway | P1.2 | P1.4 | P2.1 | S 5.1 | S5.2 |
|---|---|---|---|---|---|---|---|
| Day (7.00 - 19.00) | A | 07 - 25 | 1710 | 60 | 20 | 478 | 102 |
| | | 25 - 07 | 1035 | 51 | 9 | 273 | 62 |
| | D | 07 - 25 | 1831 | 65 | 21 | 484 | 97 |
| | | 25 - 07 | 995 | 60 | 13 | 370 | 75 |
| Evening (7.00 - 19.00) | A | 07 - 25 | 141 | 37 | 7 | 133 | 20 |
| | | 25 - 07 | 96 | 7 | 1 | 18 | 11 |
| | D | 07 - 25 | 90 | 34 | 2 | 44 | 14 |
| | | 25 - 07 | 67 | 22 | 1 | 27 | 14 |
| Night (7.00 - 19.00) | A | 07 - 25 | 25 | 27 | 0 | 42 | 20 |
| | | 25 - 07 | 30 | 8 | 0 | 10 | 24 |
| | D | 07 - 25 | 30 | 3 | 0 | 22 | 32 |
| | | 25 - 07 | 24 | 6 | 0 | 7 | 7 |

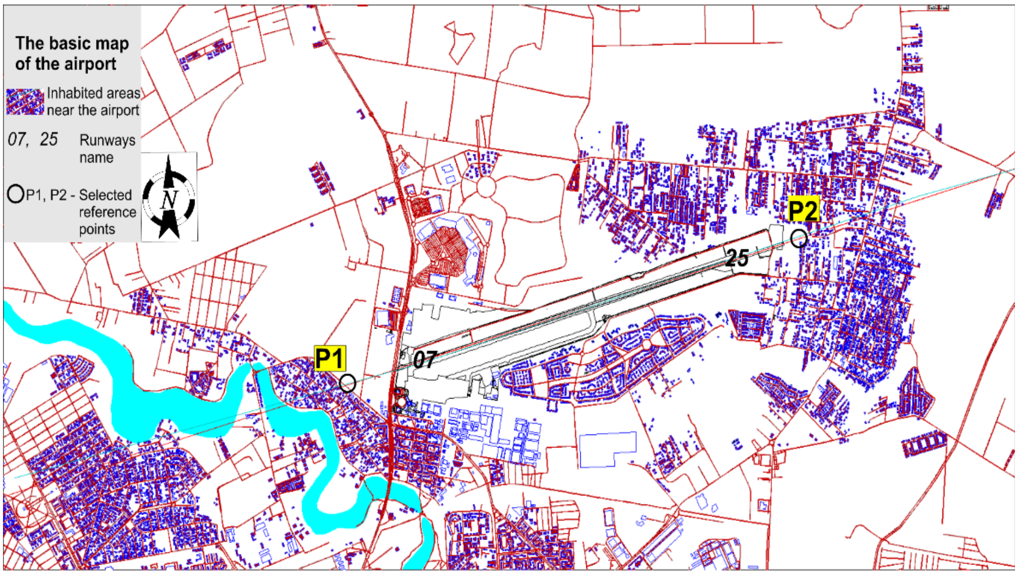


Fig. 1: The basic map of the airport (P1 and P2 are the reference points chosen in the neighborhood of the inhabited area)

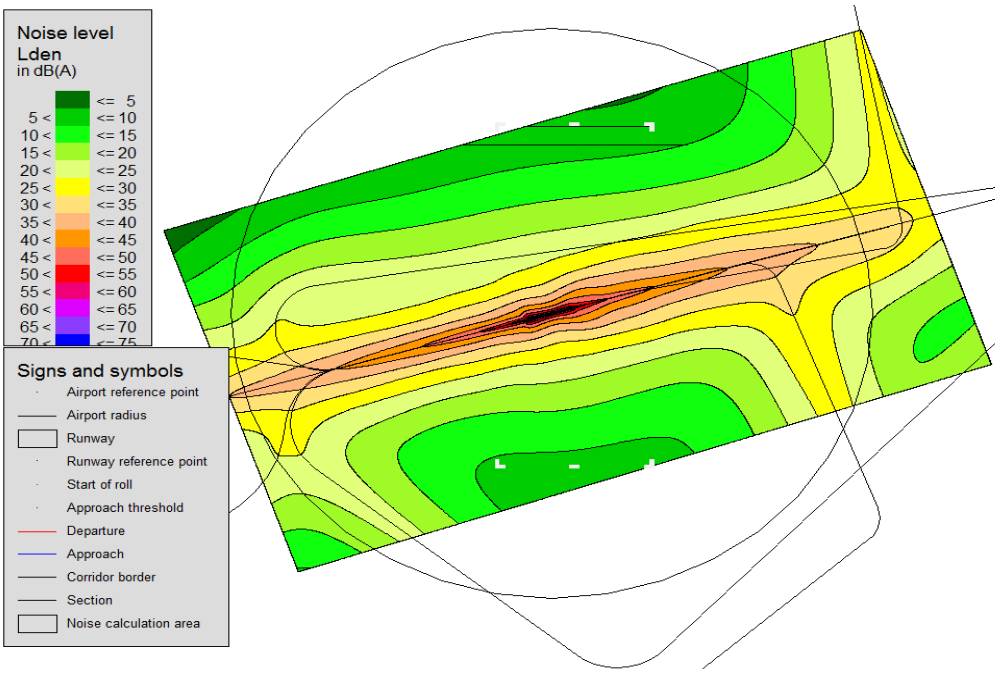


Fig. 2: Noise distribution using all flight path in the airport vicinity

In accordance with [1], noise mapping is performed for noise index values starting from 55 dB(A) for the $L_{den}$ parameter and starting with 45 dB(A) for the $L_n$ parameter. In the present case, the cartographic representation was supplemented with a range of 5 dB, starting from 50 dB(A) for $L_{den}$ and respectively starting with 40 dB(A) for $L_n$.

## 4. Airport traffic volume estimated growth criterion

In Fig. 3 and Fig. 4 are displayed the airport noise maps corresponding to year 2016. The most exposed sensitive receptors (e.g. inhabited buildings) are located in the areas at the runway end, both in zone 07 and zone 25. For estimation, two reference points P1 and P2 (Fig. 1, Fig. 2, Fig. 3, Fig. 4), are located near the most exposed receptors.

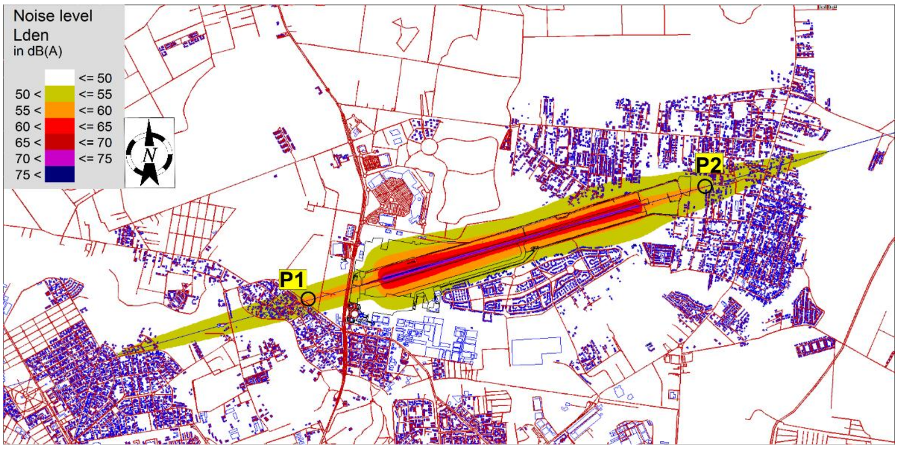


Fig. 3: Airport noise map for the $L_{den}$ parameter corresponding to the reference year 2016

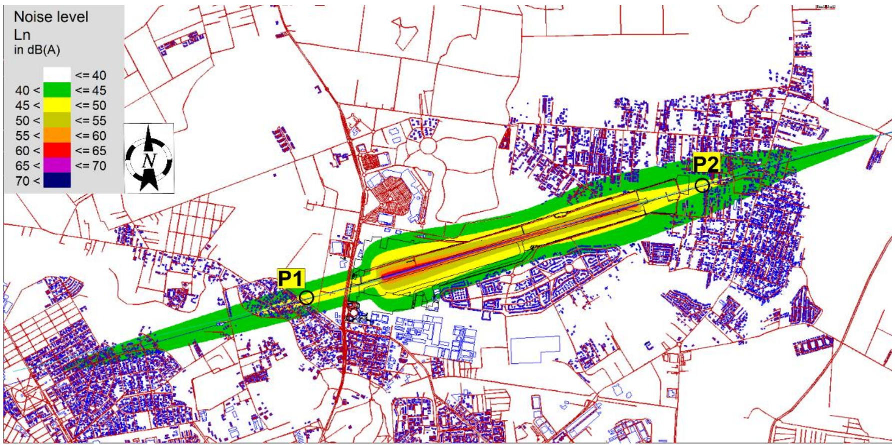


Fig. 4: Airport noise map for $L_n$ parameter, corresponding to year 2016

The proposed algorithm uses as criterion for determine the maximum increasing air traffic. The main condition is that the most exposed of the sensitive receptors remain within the admissible limits established by the legislation in terms of noise. It also admits that the volume of airport traffic multiplies by K times, assuming the equal distribution of movements by aircraft groups, on hourly intervals and in directions similar to those in reference year 2016.

According to [7], we consider the maximum admissible limits imposed by legislation for $L_{den,adm}$ equals to 70 dB(A) and $L_{n,adm}$ equals to 60 dB(A).

Table 2 represents the computed values for $L_{den}$ and $L_n$ in points $P_1$, $P_2$ and the variation from the maximum values imposed by legislation.

*Table 2*

**The noise index values at the selected reference points**

| *Parameter* | $P_1$ | $P_2$ |
|---|---|---|
| $L_{den,P_i}$ [dB(A)] | 56,0 | 55,0 |
| $L_{n,Pi}$ [dB(A)] | 47,3 | 46,3 |
| $\Delta L_{den} = L_{den,adm} - L_{den,P_i}$ | 14,0 | 15,0 |
| $\Delta L_n = L_{n,adm} - L_{n,P_i}$ | 12,7 | 13,7 |

The most disadvantageous difference is the value of 12.7 dB (A), corresponding to the point P1, for $L_n$ being the one to be used in the calculation of the allowable multiplication of airport traffic.

In the above assumption of proportions, considering the volume of traffic in 2016 as a single source, and the traffic volume is predicted to be K times higher, the $L_{n,adm}$ relation is:

$$L_{n,adm} = L_{n,P1} + c + 10 * \lg(K) \tag{9}$$

where:

- $L_{n,P1}$ represents the $L_n$ value, in point $P_1$ and $c$ is an additional constant introduced for a conservative approach;
- constant $c = 3\text{dB}$ have been introduced for a conservative approach to the assessment, in order to provide a 3dB reserve for the $L_n$ index, in the vicinity of the most exposed receiver - $P_1$. The chosen value introduces an additional upper limitation in the assessment of the air traffic volume.

In the above assumptions, value K become:

$$K = 10^{\frac{L_{n,adm} - L_{n,P1} - c}{10}} = 10^{\frac{60 - 47.3 - 3}{10}} = 9.3 \tag{10}$$

So, a K = 9.3 traffic multiplication factor has emerged. Fig. 5 and Fig. 6 describe the noise maps for this multiplied traffic scenario.

So, the environmental capacity - noise component:

$$C_{env,noise} = K * ExistingTraffic$$

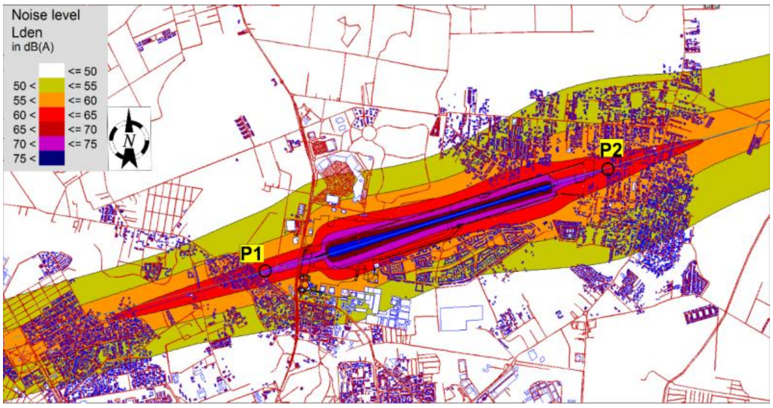


Fig. 5: Airport noise map for the $L_{den}$ parameter, when airport traffic was multiplied by 9.3 times

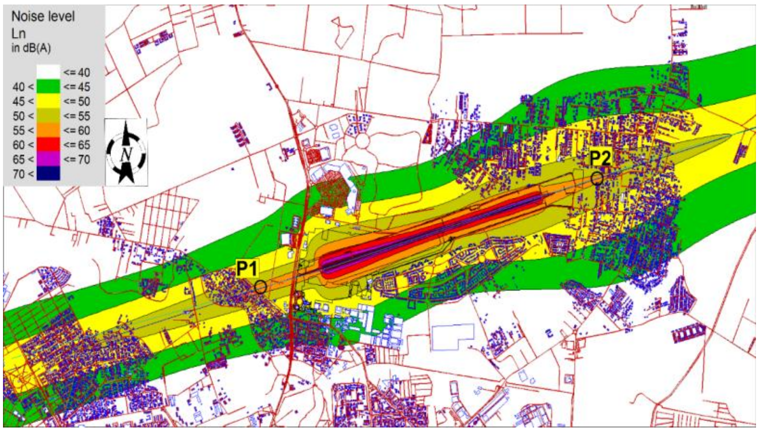


Fig.6: Airport noise map for parameter Ln, when airport traffic was multiplied by 9.3 times

## 5. Conclusions

The presented procedure has the following advantages:

- the proposed and presented working procedure can be used to obtain an *environmental capacity of airport* quantification for noise, considering that taking the most sensitive receptors as reference points, the acceptable degree of increase in volume of air traffic is established while maintaining the environmental conditions within the legal limits;
- the reductions needed to be obtained by the measures applied [8], [9], [10] to the most exposed receivers can be easily estimated in order to increase the environmental capacity of the airport by observing the "Balanced Approach";
- the data used in the strategic mapping is obtained based on the proportions of the different categories of aircraft operating at the airport, as well as the effect of long-term local weather conditions on the operating directions of the aircraft, and

the accuracy of the forecast is influenced by the stability of these proportions and meteorological conditions.

- the method presented in this article has the advantage of using the information obtained through the strategic mapping of the noise.
- The Environmental Capacity parameter ($C_{env}$), which is determined by using the results of the strategic noise maps, can be proposed as an indicator of the level of supportability of the temporary variations of the air traffic;
- $C_{env,noise}$ expresses the degree of permissiveness of small margin certification aircraft, regulated by [10].

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