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MODELAREA ŞI TELESUPRAVEGHEREA VIBRO-ACUSTICĂ AEROPORTUARĂ

AIRPORT VIBROACOUSTIC MODELING AND SURVEILLANCE

PhD student: **Ing. Mihnea-Andrei Magheți**

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CONTENTS

CHAPTER 1 — INTRODUCTION

Airport noise is an important component in assessing the quality of the environment. It is a factor that can affect the health of airport staff, aircrew and people living in the vicinity of the airport.

At international level, programmes, rules, directives and laws are introduced to limit airport noise levels and keep it within acceptable limits.

The complexity of the theoretical and practical problems related to airport noise, such as the identification of noise abatement measures, requires a modern approach consisting of the use of site monitoring systems and calculation programmes to assess in detail the exposure of the population in the vicinity of the airport.

Air transport noise is known to be one of the main problems that can limit the increase in airport capacity, so a sustained and balanced policy to mitigate noise levels is needed at and around airports in order to reduce the exposure of the population to high noise levels.

The application of Regulation (EU) No 598/2014 of 16 April 2014 requires a thorough knowledge of the influence of 'marginally certified aircraft'.The approach used in this paper provides a real basis for quantifying the proportion of such aircraft and the influence of their existence in the total flow of aircraft entering a sea airport.

The future development of air traffic requires a complex noise control system. Reducing public exposure to noise is one of the main activities to be addressed.

Noise modelling is the means by which noise mapping is carried out in the vicinity of the airport, quantifying the exposure of the population to different noise levels.

A knowledge of public exposure to noise influences a number of decisions on reducing exposure, such as: redistribution of air traffic at different intervals of the day, regulations on the composition of air traffic, etc.

Air noise monitoring can provide a real-time database, helping to obtain more accurate data and determine a wider range of noise factors.

Aircraft and engine manufacturers are currently taking initiatives to reduce aircraft noise, which currently has a significant negative effect on human communities around large and small airports. Mitigating the noise impact continues to be a major challenge and this issue is being tackled in a number of directions. The success of this objective depends very much on a good understanding of the relationship between the noise level produced and the type and extent of its effects.

One way to illustrate the magnitude of noise impact is the design of noise maps. They provide detailed representations on the calculation of the exposure levels of human communities around airports to aircraft noise and the generation of noise curves.

The noise modelling process involves the use of an appropriate modelling method, its construction and maintenance, which is composed of a noise model and a database of characteristics for certain types of aeroplanes.

Due to the combined influences of acoustic and non-acoustic factors, it is difficult to determine noise-response relationships. In general, the practical noise assessment methodology must also take into account the communities involved.'As effects on the community can only be described in statistical terms, noise exposures are usually defined only as noise mediations over long periods of time and at representative locations' [1].

Modelling elements are limited to airborne noise — airborne noise in the vicinity of the aerodrome."This noise includes take-off and landing ground rolling noise and excludes runway rolling noise of other aircraft within the aerodrome perimeter, which is referred to as *ground noise*.The contribution of this noise to the configuration of noise curves outside the airport boundaries is negligible. This does not mean that ground noise does not have adverse effects on local communities, but that is why ground noise is usually assessed separately from air noise.

ECAC did not issue guidance for measuring and assessing this noise comparable to the directives issued in the case of air noise "[1].

The paper comprises 8 chapters as follows:

Chapter 1:*Introduction* — a presentation of the noise problem in the vicinity of airports. Air transport is a growing global industry and plays a particularly important role in the existence of society and in the functioning and development of the world economy. The environmental problems posed by the existence of air transport are among the most important, including air pollution and noise emissions.

Chapter 2:*Theoretical elements in airport acustics* — from the wave equation are defined the required quantities in the acoustic field description as well as modern techniques for measuring and processing acoustic signals.

Chapter 3:*Legislation and regulatory directives in the field of noise* — legislation on rules on permissible limits and legislation on how to achieve noise recording of airport noise have been taken into account.

Chapter 4:*Airport noise modelling* — mainly the segmentation method is used to calculate noise levels at a point in the calculation network in accordance with*”ECAC.CEAC Doc.29, 3 rd edition, Vol. 1: Methodology for Computing NoiseContours around Civil Airports, Applications Guide. European Civil Aviation Conference, 2005”*

Chapter 5:*Case study 1 — Assessment of the noise environmental capacity of an airport* — theenvironmental capacity is one of the components that is taken into account when estimating the capacity of an airport. Airport traffic growth is an attractive measure in many situations. However, technical, economic, flight security, meteorological and environmental constraints limit the possibility of this increase. This chapter deals with environmental constraint from the point of view of noise.

Chapter 6:***Case study 2 — Analysis of noise aspects from access to marginally certified aircraft at Henri Coanda International Airport Bucharest***.Aircraft noise is often perceived by the Community as one of the major sources of discomfort, the European Parliament and the Council of the European Union, by Regulation (EU) No 598/2014 of 16 April 2014, in accordance with Article 5 (3), states that "the need to manage aircraft noise in a balanced approach, comprising four mainelements:

- the foreseeable effect of a reduction of aircraft noise at source;
- land-use planning and management;
- noise abatement operational procedures;
- the application of operating restrictions to marginally certified aircraft (MMC) only after taking into account the other measures of the Balanced Approach, not in the first instance.’

This chapter aims to quantify the situation of aircraft with access to the airport, including marginally certified aircraft, in order to provide the administration with an objective basis for possible decisions to manage noise problems.

Chapter 7 *Experimental surveys of noise generated by an aeroplane on the ground and in the air at take-off and landing*.This chapter schematically presents a turbomotor with noise sources: intake system, compressor, combustion chamber, turbine, gearbox, reactive jet and corresponding noise: noise of rotary components (compressor, fan) and jet noise (combustion chamber, turbine, primary and secondary jet noise).

Aircraft noise reaches very high sound pressure levels in a wide range of frequencies, both frequently low, even infrasonore, and high frequencies. Each aeroplane type has characteristics of the noise generated, depending on the type of engine, the type of propulsion, the position of the engine, the type of operation, the environmental conditions, etc. For all aeroplane categories, the noise levels generated increase by thrust and speed, so that the jet noise of the gases becomes dominant in the total noise generated.

Aircraft noise is highly directivity and these directivity features are stationary on the ground under extreme operating conditions from idle to maximum speed with one or all engines in operation.

Measurements have been taken during the period when background noise is low and do not influence the results of measurements and reflective surfaces are absent or long distance. The measurement chain used consisted of a multi-channel 01-dB Metravib-Orchestra system with 12 simultaneous procurement channels. The 12 microphones were equidistant, within a semi-circle of radius of 24 m, with an imaginary centre in the dummy centre of the aeroplane. Acoustic radiation shall be considered symmetrical in relation to the axis of the aeroplane.

This chapter presents the results of noise measurements when aircraft overflight when taking off and landing on the runway at Otopeni Airport. The noise generated by each individual aircraft has been recorded for take-off, during the period between the moment of lifting from the ground, passing over the microphone and its removal. In the case of landing, the recording was made from the aircraft visualisation, passing over the microphone and landing. The processing of the results of the noise measurement was presented as the variation of sound pressure over time, as a variation of the sound pressure level and as spectral representation by sequential sequencing of spectrograms, known as *cascade representations*, using the specialised software dB- RTA.The results of the measurements for the highest noise levels may lead to assessments of noise levels in inhabited neighbourhoods, considering Law 1/r in the case of free field propagation.

Chapter 8:*Conclusions* — This chapter sets out the conclusions drawn from the work carried out in this paper, highlights the novelties and the usefulness of further expanding and deepening these activities. Thus, the noise assessment of environmental capacities is an important part of estimating the capacity of an airport, given the need for compatibility between the operation of the airport and environmental requirements.

CHAPTER 3 — LEGISLATION AND DIRECTIVES DEFINING NOISE

Environmental Noise Directive (2002/49/EC)

The outcome of 4 years of continuous work by international experts in the field of noise, combined with the ensuing discussions in the Council and the European Parliament, resulted in the publication of the Environmental Noise Directive on 25 June 2002 (briefly END) aimed at assessing and managing environmental noise. The aim of this Directive is to define an approach common to all Member States, with the intention of avoiding, preventing or reducing harmful effects, including derailment due to exposure to environmental noise by residents of residential areas.

Within the framework of that directive, the following actions were envisaged:

- “determination of exposure to environmental noise by noise mapping by assessment means common to the Member States;
- ensuring that information on environmental noise and its effects is accessible to the public;
- the adoption of action plans by the Member States, based on the results of noise mapping, with a view to preventing and reducing environmental noise where necessary and in particular where exposure levels may have harmful effects on human health and preserving the quality of the environment where it is quiet.’ [7]

Directive 2002/49/EC is the legal basis available to Member States for assessing and managing environmental noise. Monitoring noise problems at intervals of at least 5 years by carrying out strategic charts for road traffic, rail traffic, air traffic and industrial activity involves assessing the exposure of the population to different noise levels and drawing up action plans to reduce these levels where appropriate, or to maintain noise ambition where this is favourable.

Directive 2002/49/EC lays down the noise descriptive indices and calculation methods for the four types of sources listed above.

The European Commission has published "Commission Recommendation on guidelines on revised provisional calculation methods for industrial, aviation, road and rail noise

Thus, the following methods of application are recommended, depending on the type of noise:

- Industrial noise
  - ‘SR ISO 9613-2: 2006 Acoustics — Continuation of airborne noise. Part 2: The general calculation method. The corresponding emission data (input data) for this method can be obtained from field noise measurements.
  - ISO 8297: 1994 — Acoustics — Determination of sound power levels of multi source industrial plants for evaluation of sound pressure levels in the environment — Engineering method.
  - EN ISO 3744: 1995 Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essential free field over a reflecting plane.
  - EN ISO 3746: 1995 Acoustics — Determination of sound power levels of noise sources using an enveloping measurement over a reflecting plane.’
- Aviation noise
  - “ECAC.CEAC Doc. 29 Report on Standard Method of Computing Noise Contour around Civil Airport” 1997. For flight path modelling, the segmentation technique referred to in section 7.5 of [10] shall be used.
- Road traffic noise
  - ‘French national calculation method *NMPB-Routes-96 (SETRA-CERTU-LCPCCSTB)*, referred to in the document issued on 5 May 1995 on road infrastructure noise, Article 6 and French *standard XPS* 31-133.’
- Rail traffic noise
  - Dutch national calculation method published in ‘Reken — en Meetvoorschrift Railverkeeslawaai’ 96, Ministerie Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 20 November 1996’.

These methods have adapted to the definitions of Lzsn and Lnight. Set out in Annex 1 of [10].

Strategic noise maps

A strategic noise map is a map designed to illustrate noise levels and assess noise exposure in the area of concern. Strategic noise maps will be used to provide the data to be reported to the European Commission and are sources of information to citizens as the information base for action plans. thus, a strategic noise map constitutes a presentation of data in various aspects, such as:

- “existing situation, a future or forecast situation, in terms of a noise indicator;
- the exceeding of a limit value;
- the estimated number of dwellings, schools and hospitals in an area that are exposed to a specified noise indicator value;
- the estimated number of inhabitants located in an area exposed to noise.” [7]

Definitions of noise indicator level for day-evening — night — Lzsn

The day-night (Lzsn) indicator level — in decibels (dB), is calculated according to the following formula [11]:

$$L_{zsn} = 10\lg\frac{1}{24}\left(12 * 10^{\frac{Lziua}{10}} + 4 * 10^{\frac{Lseara+5}{10}} + 8 * 10^{\frac{Lnoapte+10}{10}}\right) \quad (0\text{-}1)$$

in which:

- ‘Lday is the long-term average A-weighted sound pressure level, measured in one year, determined over all days in a year;
- Levening is the long-term average A-weighted sound power level, measured in one year, determined in all sera in a year;
- Lnight is the long-term weighted average sound power level, measured in one year, determined over all nights in a year;
- the day is 12 hours, the evening is four hours and the night is eight hours.

The sound (or noise) exposure level corresponding to a single event is expressed in the formula (0-2)

$$L_E = 10\ \lg\left[\frac{1}{t_0}\int_{t_1}^{t_2} 10^{L(t)/10} dt\right] \tag{0-2}$$

Where t_0 is a reference time. The integration range [t_1, t_2] is chosen to ensure that (almost) the entire energy content of the event has been taken into account. Very often, the t_1 and t_2 limits are chosen to divide the period for which level L (t) is within the limits of L_{Amax} — 10 dB.This period is known as the time period in which the noise level corresponding to the acoustic event is greater than L_{Amax} — 10 dB.

The exposure level equations above can be used to determine event levels when the entire time history of L (t) is known.

Such historical noise modelling methodology is not defined in the recommended methodology. Exposure levels are calculated by summing the log of segment values, each of the partial levels defines the contribution of only one selected flight path segment.’ [10]

Equivalent noise level

L_{eq}Is the sound pressure level over time T and is given by the relationship [10]:

$$L_{eq} = 20\, lg\left(\frac{1}{T}\int_0^T (p^2/p_0^2) dt\right) \tag{0-3}$$

Where p is the instantaneous sound pressure measured over the entire frequency spectrum and p_0 is the reference sound pressure of 20 μPa. The averaging time T shall be specified and shall be in the order of seconds, minutes or hours chosen according to the stationary or non-statistical character of the noise assessed.

The equivalent sound level may be measured with a sound-level meter or any similar apparatus with analogue or digital processing. Since the definition L_{eq} takes into account both the size and duration of the acoustic signal (noise), this physical size is one of the most widely used to assess environmental noise. It is also the most descriptive parameter in relation to the psychological effects of noise.

Taking into account the relationship between sound intensity and sound pressure, which applies to both flat and spherical waves, a relationship between the sound intensity level and the sound pressure level may be written [10]:

$$L_I = L_p + 10\, log_{10}\frac{p_o^2}{\rho_o c I_o} \tag{0-4}$$

In practical terms, the second term of the right member is very small and as a result the sound pressure level can be considered to be equal to the sound intensity level. This finding is important in the acoustic measurements when the sound pressure is usually measured.

If the sound pressure is expressed on the A weighting curve, the equivalent A-weighted pressure level shall be obtained: [10]

$$L_{Aeq} = 10\, lg\left(\tfrac{1}{T}\int_0^T ({p_A}^2/p_0^2) dt\right)(\text{DB}) \tag{0-5}$$

This equivalent sound level may be weighted B, C or D according to the weighting curve used.

Weighted equivalent sound levels

'The time-weighted equivalent sound levels representing the significant sound energy received from the aircraft shall be generically expressed by the following formula, summing all noise events N in the time interval T_0 to which the noise index applies

$$L_{eq,W} = 10 \ \lg\left[\frac{t_0}{T_0}\sum_{i=1}^{N} g_i \cdot 10^{L_{E,i}/10}\right] + C \qquad (0\text{-}6)$$

where:

- $L_{E,i}$istheexposurelevelofasinglenoiseeventof thenoiseevent$i$.
- $G_i$isadailyweightingfactor(usually definedforday,eveningandnight).Eisacoefficientforthenumberofflightstakingplaceduringspecificperiods.
- Cconstant that mayhavedifferentmeanings(standardisation constant, seasonal adjustment, etc.).' [12]

Calculation of the resulting noise level at a receiving point in case of simultaneous action of more than one source

'The continuous equivalent sound pressure level for a duration T at a receiver point shall be determined with the relationship:

$$L_{eq,T} = 10\, lg\left(\sum_{i=1}^{n} 10^{\frac{L_{eq,T,i}}{10}}\right) \qquad (0\text{-}7)$$

where:

- N is the number of sources that generate noise at the receiver point
- $L_{eq,T,i}$ Is the continuous equivalent sound pressure level produced at the receiver point by source i over a reference period T.' [10]

CHAPTER 4 — MODELLING OF AIRPORT NOISE

The main contribution to aircraft noise is the unit of power (one or more engines), with aerodynamic noise significantly lower, it can be perceived in particular on landings when engine thrust is minimal and the noise produced by them is also lower.

Noise maps in an area covering the territory of airports and adjacent areas shall be carried out in order to determine the impact caused by aircraft noise around airports, in particular through the affected area and its amplitude.

The noise map shall take into account the following aspects:

- the determination of the estimated noise according to one or more descriptive parameters;
- identifying sensitive receptors (dwellings, hospitals, schools) and estimating the number of people exposed to different noise levels and when the permissible limits are exceeded.
- The noise map shall be carried out by appropriate calculations in order to establish the contours with the same value of the noise index required to be determined. The value of the noise index shall be obtained taking into account the totality of individual acoustic events related to aircraft movements that occur over a specified period of time.

The type of aircraft, the engines used and the procedures applied for regulating engine power, flares, flight path distance and ground point, airspeed and air speedusedby aircraft, weather conditions, etc. are factors that determine the noise generated at a receiving point.

In order to highlight the theoretical bases of the modelling and noise contouring process in the vicinity of the airport, the method of calculating the noise levels produced by individual aircraft occurrences shall be presented. It also assesses how noise levels can be assessed at a given point as a result of summing these levels at an event or during a day, week or year, day and night.

Measurements or assessments to determine airport noise shall mainly include the following descriptive parameters:

- L_{pA}A-weighted or L_{pC} C-weighted linear sound pressure levels;
- Sound exposure levels, L_{AE}
- $L_{p,A,eq,max,1s}$is the maximum A-weighted sound pressure level over 1s of an event;
- L_{day} Represents the sound pressure level during the day, i.e. in the evening$L_{evening}$, at night, L_{night} and, in the evening, L_{den} in the night.

Noise contours shall be determined for aircraft movements (take-offs and landings) in the vicinity of the airport up to distances where the descriptive parameters L_{den} and shall L_{night} have values of at least 55 dB (A) for L_{den}respectively 45 dB (A) forL_{night}.It is clear that these contours of equal noise level can also be achieved for other descriptive parameters among those listed above.

AIRPORT NOISE — MEASUREMENT AND CALCULATION MODEL

Direct measurement takes into account the effects that are difficult to analyse in theory, as follows:

- soil absorption, if there is a significant distance between the source and the receiver point and is influenced by topography;
- weather factors — wind, temperature, humidity.

Direct measurement can be an important means of research to shape airport noise by analysing these particular effects. It also allows for an accurate determination of existing sound levels at well-localised locations over well-defined time periods.

Measurement in areas where construction is already built and where noise exists makes it possible to define the sound level perceived at a given point in time with good precision. However, measurement does not allow for predictions for future situations."The representativeness of the measurement is limited.

Field measurement ensures that the sound level is estimated at a well-located/established point during a period of time coinciding with the measurement time. However, the characterisation of the acoustic environment in an area in order to appreciate the discomfort to the population requires knowledge of average noise levels over a longer period*of time (sometimes several months up to one year).*

The measurement is dependent on meteorological conditions. These effects are rarely quantified (*measurements of wind, temperature, humidity, rainfall or snowfall).A*reversal of the temperature gradient, e.g. from hot to cool weather, may change the measurement result to a point of 4-5 dB (A). "[6]

A more advanced method of measuring noise levels in the vicinity of airports is regulated by ISO Standard 20906: 2009 — '*Acoustics. Automatic surveillance of aircraft noise in the vicinity of airports".*Thisescribesa system for recognising acoustic occurrences based on threshold that may be necessary to separate aircraft noise events from each other and to separate airborne acoustic events from those generated by other sources.

In particular, the standard provides information on:

- typical use of a monitoring system in the vicinity of an airport;
- the characteristics of the apparatus included in the system in order to determine continuously the noise levels at the selected receiving points;
- conditions to be fulfilled in the framework of the monitoring of an airport;
- parameters to be determined to characterise aircraft movements (landings, take-offs)
- the content of the reports and the frequency of their issuance;

- the method for assessing the expanded measurement uncertainty for the data obtained, in accordance with ISO/IEC Guide 98-3 (GUM);

The standard does not provide a method for confirming or validating noise mapping data and cannot be used for the determination, validation or confirmation of data contained in the aircraft certification report. The standard may also not be used to describe aircraft noise while on the ground, except when starting for take-off, and between point of contact with the ground and leaving the runway in case of landing.

Some studies show that people are satisfied with a particular intervention regardless of the outcome of the intervention (Hawthorne effect).For example, a study shows a subjective positive effect equivalent to noise reduction of 5 dBA at the time of informing the public of a careful noise monitoring programme around the airport.

Based on the logic scheme in Figure 4.3, using the timing of the noise level, the detection process extracts acoustic events that meet certain criteria, mainly by using time and level thresholds.

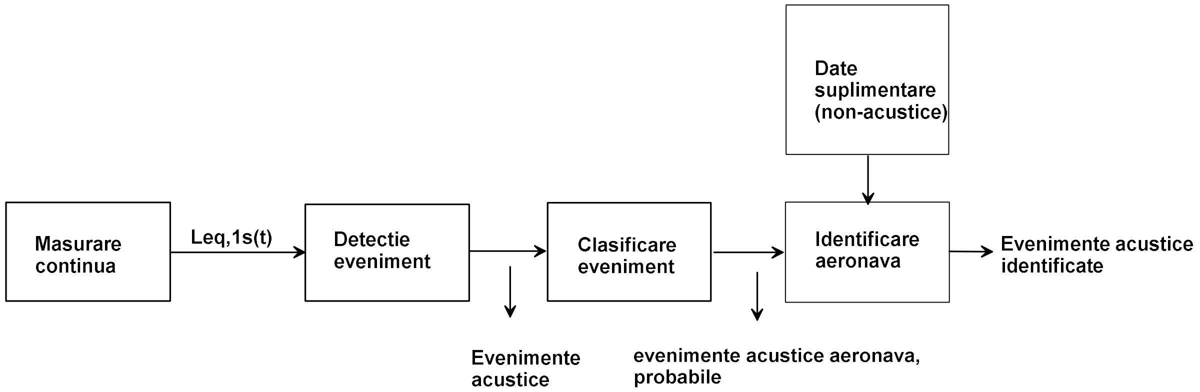

Figure 4.3 Aircraft acoustic event identification logic scheme

METHODOLOGY FOR CALCULATING NOISE LEVELS

Two types of noise contours can be calculated mathematically depending on the observer's need, namely for the purpose of:

- noise history recording. Be based on the records of movement data, operational procedures, aircraft flight path radar data;
- prediction of noise levels, taking into account estimates of airport traffic, aircraft characteristics and flight paths at an airport.

The parameters defining the movement of the aircraft shall take into account the geometry of the flight path.

Characteristics such as the aircraft type, the parameters specific to each aircraft, mainly considering that the power of its engines determines the noise emission.

The methodology for calculating the contours recommended by European rules involves segmenting the flight path and considering each segment taken independently of the others. Route, atmospheric conditions, and operating procedures, etc. are also taken into account.

The calculation of the noise level produced by a single event, at a point on the ground, after setting the flight path, shall be considered to be the next step in the process of determining the equivalent noise level corresponding to a noise contour.

"The noise contour shall match the crowds of the noise index values. Only then can the data obtained be considered valid and reach the final stage of the noise contour generation process: post-processing and export of data. The recommended methodology involves dividing the flight path into segments.

The observed event noise level is a logarithmic summation of the contributions of all significant segments of flight paths, each of which can be calculated independently of the others ", according to Figure 4.6.[10]

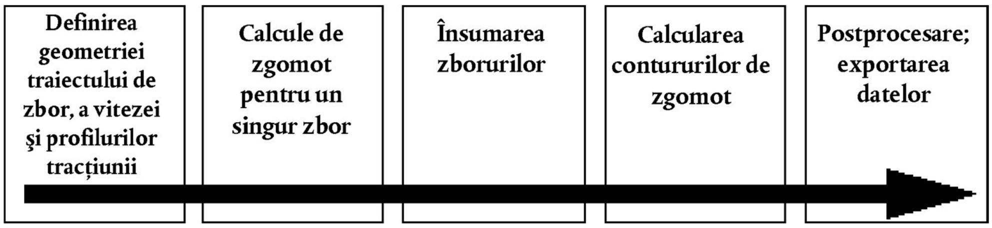

Figure 4.6 Noise contour generation process

The concept of segmentation

The following parameters shall be considered as reference, for each aircraft type: noise, Power and Range (NPD).They shall determine the perceived sound levels of the event directly underneath the aircraft.

The flight configuration shall consist of a reference speed, the flight path being straight, constant, under specified atmospheric conditions.

"For the purpose of noise modelling, the noise-related power parameter used is the *corrected net thrust*.Thus, the event reference level is adjusted for differences between atmospheric, modelled (actual) and reference conditions, as well as differences between downward and lateral radiated noise, difference due to lateral directivity (effects of engine installation) and lateral attenuation'.[10]

'For the purpose of the noise level calculation by segmentation, the flight path shall be divided into adjacent straight segments, each of which may be considered as a delimited part of an infinite trajectory for which the NPD and lateral adjustments are known. The maximum event level is the highest of the individual segment values. The integrated time level of the entire noise event is calculated by summing the noise received from a sufficient number of segments, i.e. those that make a significant contribution to the total noise level of the event.' [16]

"A reason why a simple empirical method is generally appropriate is that most noise usually comes from the nearest, usually adjacent segment — for which the nearest point of approach (CPA) to the receiver is in the segment. This means that noise estimates from non-adjacent segments can be very approximate because they move away from the receiver without significantly compromising accuracy'. [16]

CHAPTER 5 — CASE STUDY 1 — NOISE ASSESSMENT OF AN AIRPORT'S ENVIRONMENTAL CAPACITY

ESTIMATION OF THE GROWTH POTENTIAL OF AIRPORT TRAFFIC

The environmental problems associated with air transport, the most important of which are related to noise and air pollution, may create constraints that make it necessary to limit this increase.

An important constraint in increasing airport traffic is the need to limit noise emissions for sensitive receivers (residential homes, schools, hospitals) in the vicinity.

Mandatory compliance with airport environmental legislation, in particular with regard to noise and gaseous pollutants, requires air traffic to be limited to a volume called environmental capacity *(C_{ENV})*.

Based on the results of the strategic noise mapping to be carried out periodically by calculation according to [20], [21] and [10], the work presents a simple way of approximating the environmental capacity — the noise component — for the particular conditions of an airport.

The method described can be used to better exploit the information obtained from the strategic noise mapping.

In practice, the increase in airport traffic can be achieved within certain limits. In the literature [22], [24], [42], the concept of environmental capacity of an airport is used and the growth limits imposed on an airport's activity are described in order to comply with the legislation on the state of the environment in its vicinity.

In a more general approach, the concept of airport capacity defined as the minimum of three capacities is used:

$$C = min(C_{op}; C_{ec}; C_{env}) \quad (0\text{-}1)$$

where:

- C_{op} is the operational capacity of an airport that is given by the airport's available facilities (runways, aircraft access roads to different points, parking spaces, terminal capacity)
- C_{ec} is economic capacity meaning the maximum flow of passengers or aircraft that can transit through the airport if there were no restrictions;
- C_{env} the environmental capacity of an airport, meaning maximum air traffic for which environmental legislation is not infringed.

Strategic noise mapping in the vicinity of an airport is an activity that takes place with a certain periodicity (at intervals of maximum 5 years).

If the noise descriptive parameters in the vicinity of the most exposed sensitive receptors are below the limits imposed by the legislation [7], the estimation of the allowable increase in the airport's activities may be made by simple calculation, according to the following example.

The adoption of abatement measures in accordance with the *balanced approach* as described in [8] and [9] and as required by [7] increases the environmental capacity of the airport, so it is the possible development of airport traffic.

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

Dose-effect studies show that at the same exposure of the population, air transport noise is more annoying than noise from road or rail transport.

In the vicinity of many airports within the European Community, including Romania, there are inhabited areas exposed to air traffic noise. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 on the assessment and management of environmental noise sets out the activities necessary to ensure acceptable environmental conditions with regard to noise.

Noise mapping thus assesses the exposure of the surrounding population to noise and sets out the measures needed to reduce that exposure in the action plans. Prioritisation of these measures must take into account the permissible limits set by legislation as well as the number of people exposed to noise of different levels.

Based on the information contained in the strategic noise mapping for an airport, this chapter describes the assessment path of C_{env} the noise component.

For 2016, the activity at Bucharest International Airport "Băneasa" was characterised by relatively low traffic volumes.

The noise mapping method used the segmentation technique referred to in [10].The strategic noise mapping carried out for the reference year 2016 in accordance with Government Decision No 321/2005 did not reveal noise index values beyond the permitted limits set by environmental legislation [22].

An increase in traffic volumes makes the use of the airport more efficient. The increase in traffic volumes leads to higher noise levels at the airport.

The noise levels generated by the activity of the airport and their distribution in the areas near the airport depend on the number of aircraft movements (landings and take-offs), the traffic structure (proportions of different categories of aircraft) and the distribution of traffic over the three periods of the day. The periods referred to are: day — time 7.00-19.00, evening — 19.00-23.00, night — 23.00-7.00. In addition, the weather conditions of the area, in particular wind, influence the direction (meaning) of operations and thus the distribution of noise levels.

With the exception of landings and take-offs, the study does not take into account additional airport-specific noise sources: aircraft access roads at various locations within the airport, APU operations, engine test stands, lorries, buses, de-icing or cooling devices. In addition, for simulation by calculation, two traffic variants are considered:

- airport traffic for the reference year 2016;
- hypothetical increase in traffic volume up to the limit level required by Order No 152/558/1119/532-2008 in order to assess the airport's environmental capacity from the point of view of noise.

SPECIFIC ASPECTS CONSIDERED IN AIRPORT NOISE CALCULATION

In the case of air traffic noise determination, its value is determined using relatively high calculation networks (grids), with determination points spaced at 50-100 m, as opposed to mapping road and rail traffic noise or noise generated by industrial activity.

In the latter case, the noise shall be calculated in detail for all sensitive receptors using calculation scales up to 10 m.

Aircraft of different types generate different noise levels depending on the type of engines they are equipped with. It is therefore very important to use actual data specific to the type of aircraft used when calculating aircraft noise levels.

In order to limit the diversity of aircraft categories to be included in the calculation, several aeroplane types are included in a similar acoustic noise emission group based on the following characteristics: aircraft propulsion type (jet, fan or propeller turbine), engine number (1, 2, 3 or 4), fan by-pass ratio, MTOM — Maximum take-off mass (kg).

MTOM is the most relevant parameter in that list, for which the following categories are defined:

- Light aircraft: 5.700-10.000 Kg;
- Medium aircraft: 10.000-50.000 Kg;
- Heavy aircraft: 50.000-200.000 Kg;
- Very heavy aircraft: 200.000-400.000 Kg;
- Ultra-heavy aircraft: 400.000 Kg.

The method of segmentation shall be used in the noise calculation. The flight path is divided into segments characterised by their spatial positions, aircraft speed and power setting. The sound exposure level is calculated for each segment, corrected for the final length of segment, then the exposure levels are summed for all segments at each point in the calculation scale.

The definition of noise indicators L_{den} (day-evening-night) and L_n (night) are given in the following formula [10]:

$$L_{den} = 10 * lg\left[\left(\frac{1}{24}\right) * \left(12 * 10^{L_{day}/10} + 4 * 10^{L_{evening}+5/10} + 8 * 10^{L_{night}+10/10}\right)\right] \quad (0\text{-}2)$$

where:

- L_{day}(dB (A)) is a daytime noise indicator;
- $L_{evening}$(dB (A)) is the evening noise indicator;
- L_{night}(dB (A)) is the night noise indicator.

The following noise indicators shall be obtained by adapting the indices mentioned above:

$$L_{den} = 10 * lg\left[\frac{\tau_0}{T_{den}}\left(N_{d,i,j} + 3{,}16 * N_{e,i,j} + 10 * N_{n,i,j}\right) * \sum_{i,j} 10^{\frac{L_{AE,i,j}}{10}}\right] \quad (0\text{-}3)$$

The relationship between the sound exposure level L_{AE} and the equivalent continuous sound pressure level L_{eq}corresponding to a time interval T shall be [21]:

$$L_{eq} = L_{AE} + 10 * lg\left(\frac{\tau_0}{T}\right) \quad (0\text{-}4)$$

where:

- $\tau_0 = 1s$
- And T [s] is the reference time period chosen.

The relationships below define the parameters L_d (L_{day}),L_e ($L_{evening}$), L_n (L_{night}) at a point:

$$L_d = 10 * \lg\left(\frac{\tau_0}{T_d} * \sum_{i,j} N_{d,i,j} * 10^{\frac{L_{AE,i,j}}{10}}\right) \quad (0\text{-}5)$$

$$L_e = 10 * \lg\left(\frac{\tau_0}{T_e} * \sum_{i,j} N_{e,i,j} * 10^{\frac{L_{AE,i,j}}{10}}\right) \quad (0\text{-}6)$$

$$L_n = 10 * \lg\left(\frac{\tau_0}{T_e} * \sum_{i,j} N_{e,i,j} * 10^{\frac{L_{AE,i,j}}{10}}\right) \quad (0\text{-}7)$$

$$L_{den} = 10 * lg\left[\frac{\tau_0}{T_{den}}\left(N_{d,i,j} + 3{,}16 * N_{e,i,j} + 10 * N_{n,i,j}\right) * \sum_{i,j} 10^{\frac{L_{AE,i,j}}{10}}\right] \quad (0\text{-}8)$$

where:

- $T_{den}$is the duration of the day + evening + night (24 h = 86400 s);
- $T_n$is the night duration (8 h = 28800 s);
- $T_e$is the duration of the series (4 h = 14400 s)
- $\tau_0 = 1s$;
- $N_d N_e N_n$Is the number of movements during a day (12 hours), one evening (4 hours) and one night (8 hours);
- I and j are the runway index and group index respectively.

ANALYSIS OF AIRPORT NOISE VALUES REPORTED AT 2016 LEVEL

Tabel 1Is the available data obtained from the *Băneasa* airport administration which represents the lists of aircraft which landed and took off throughout the year 2016 and the hours during which these operations took place.

The data are organised into groups of noise, distribution, landing/take-off direction and time distribution over the three characteristic intervals of the day.

Table 1 Emissions data used, including aircraft movements organised according to appropriate noise groups

Period	Operation	Runway	P1.2	P1.4	P2.1	S 5.1	S5.2
Day (07.00-19.00)	A	07-25	1710	60	20	478	102
		25-07	1035	51	9	273	62
	D	07-25	1831	65	21	48	97
		25-07	995	60	13	370	75
Evening (19.00-23.00)	A	07-25	141	37	7	133	20
		25-07	96	7	1	18	11

	D	07-25	90	34	2	44	14
		5-07	67	22	1	27	14
Night (23.00-07.00)	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

Figure 5.2 depicts the basic map of Băneasa airport, with the choice of measurement points (P1 and P2) as the chosen reference points in the vicinity of the inhabited area.

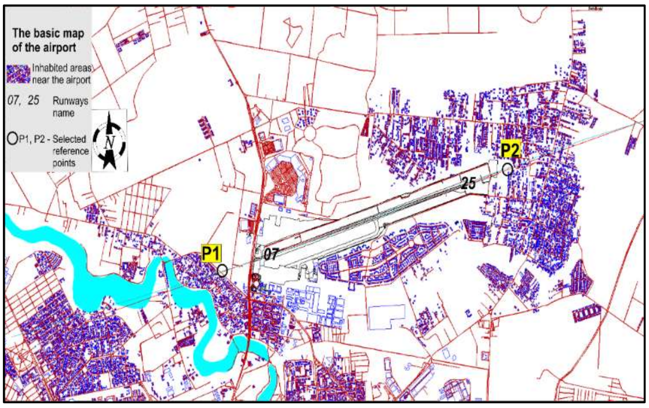

Figure 5.2 Baseline map of Baneasa airport with the choice of measurement points (P1 and P2)

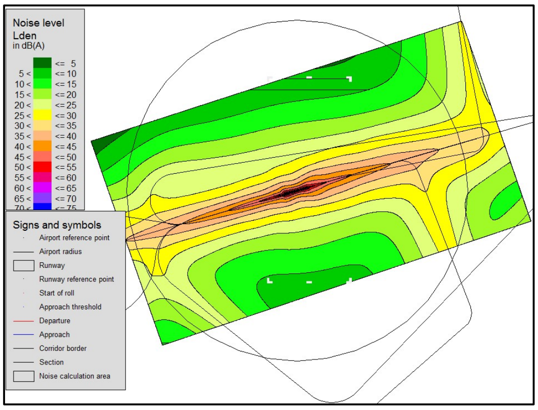

Figure 5.3 Noise distribution using all flight paths in the vicinity of the airport.

According to [20], the noise mapse is performed for noise index values starting at 55 dB (A) for the parameter L_{den} and from 45 dB (A) for the parameter L_n.

In the present case, the chart representation (Figure 5.3) was supplemented by a range of 5 dB (A), starting at 50 dB (A) for L_{den} and 40 dB (A) for L_n respectively.

CRITERIA FOR ESTIMATING THE INCREASE IN AIRPORT TRAFFIC

Figure 5.4 and Figure 5.5 show the airport noise maps for 2016. The most exposed sensitive receptors (e.g. inhabited buildings) are located in the areas at the end of the runway, both in zone 07 and in zone 25. For the estimation, two P1 and P2 reference points are located close to the most exposed receptors.

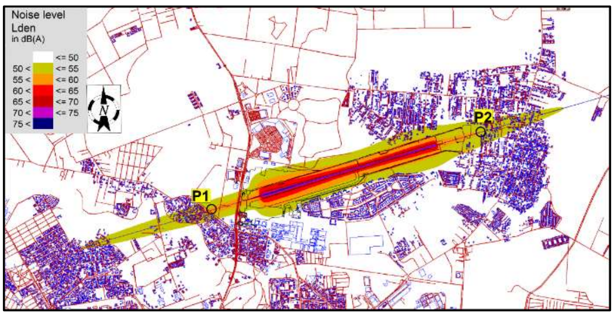

Figure 5.4 Airport noise map for the parameter Lden corresponding to the reference year 2016

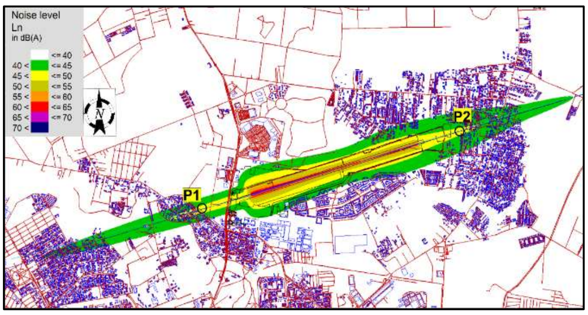

Figure 5.5 Airport noise map for parameter Ln, corresponding to 2016

The proposed algorithm uses as a criterion to determine the air traffic associated with the maximum increase. The main condition is that the most exposed sensitive receptors remain within the permissible noise limits set by the legislation. It also accepts that the volume of airport traffic is multiplied by K, assuming the same distribution of movements by group of aircraft, at times and in directions similar to those in the reference year 2016.

According to [22], we consider that the maximum permissible limits imposed by the legislation are $L_{den,adm}$70 dB (A) and $L_{n,adm}$60 dB (A).

Tabel 2Is the calculated values for L_{den} and $L_n$points at paragraphs P1, P2 and the variation from the maximum values required by the legislation.

Table 2 Noise index values at selected reference points

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

The most disadvantageous difference is the value of 12.7 dB (A), corresponding to point P1, forL_n, being that to be used in the calculation of the permissible multiplication of airport traffic.

Under the above assumption of proportions, considering the traffic volume in 2016 as a single source and the volume of traffic being K times higher, the relationship $L_{n,adm}$ becomes:

$$L_{n,adm} = L_{n,P1} + c + 10 * lg(K) \qquad (0\text{-}9)$$

where:

- $L_{n,P1}$ Is L_n the value in point P1 and c is an additional constant introduced for a conservative approach;
- The value of the constant $c = 3$ dB for a conservative assessment approach has been taken to ensure a 3 dB reservation for the index in $L_n$the vicinity of the most exposed receptor — P1. The value chosen introduces an additional upper limit in the assessment of the volume of air traffic.

In the above assumptions, the value of the constant K becomes:

$$K = 10^{\frac{L_{n,adm} - L_{n,P1} - c}{10}} = 10^{\frac{60-47,3-3}{10}} = 9,3 \qquad (0\text{-}10)$$

This resulted in a traffic multiplication factor K = 9.3.

Figure 5 5 and Figure 5 6 describe the noise maps for this multiple traffic scenario.

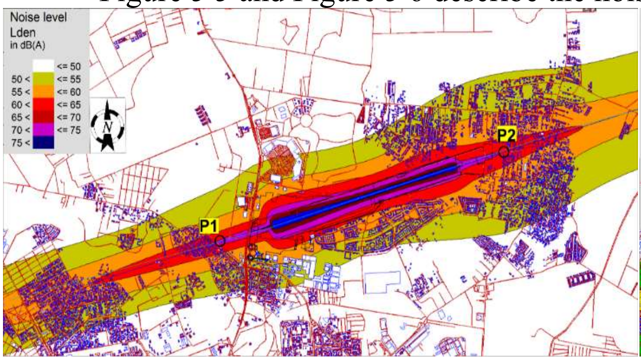

Figure 5.6 Airport noise map for Lden parameter, when airport traffic was multiplied by 9.3 times.

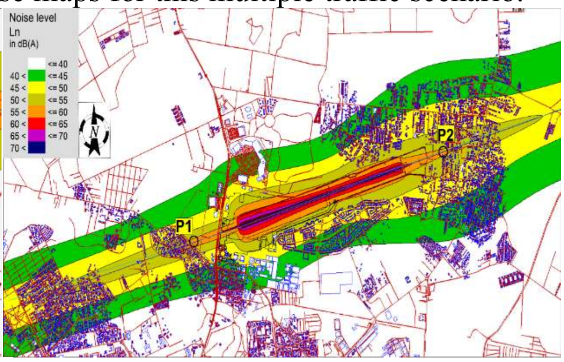

Figure 5.7. Airport noise map for parameter Ln, when airport traffic was multiplied by 9.3 times.

CONCLUSIONS

The current chapter represents a rapid method of approximating the growth potential of airport traffic, starting with the situation at some point in time.

The method presented has the following advantages:

- The method described may be used both for forecasting the development of air traffic at an airport, but may also be used as a measure in a noise reduction action plan when its levels are within the area of the permissible limits;

- The reductions required to be achieved by the measures applied to the most exposed receptors can easily be estimated to increase the environmental capacity of the airport by following the *Balanced Approach*;
- The data used in strategic mapping shall be obtained on the basis of 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 aircraft's operating directions and the accuracy of the forecast, influenced by the stability of those proportions and the weather conditions;
- The method presented has the advantage of using strategic noise mapping information;
- The parameter *Environmental Capacity* (C_{env}), determined using the results of strategic noise charts, may be proposed as an indicator of the level of tolerability of temporary air traffic variations;
- It $C_{env,noise}$ also expresses the degree of permissiveness of marginally certified aircraft regulated by [34].

CHAPTER 6 — CASE STUDY 2 — ANALYSIS OF NOISE ISSUES ARISING FROM ACCESS OF MARGINALLY CERTIFIED AIRCRAFT TO HENRI COANDĂ INTERNATIONAL AIRPORT BUCHAREST

INTRODUCTORY ASPECTS OF AIRPORT SUSTAINABLE DEVELOPMENTS

This chapter aims to quantify the situation of aircraft with access to the airport, including aircraft with MMC, in order to provide the administration with an objective basis for possible decisions to manage noise problems.

According to the Regulation, the following definitions are identified for:

- "*airport* — an airport having more than 50.000 civil aircraft movements per calendar year (one movement meaning a take-off or landing), based on the average number of movements over the last three calendar years prior to the noise assessment.
- *Aircraft with a marginally* certified margin —*a civil aircraft that is certified within the limits set out in Volume 1, Part II, Chapter 3 of Annex No 16 to the Convention on International Civil Aviation, signed in Chicago on 7 December 1944 (hereinafter referred to as the Chicago Convention), with a cumulative margin of less than 8 EPNdB (effectively perceived noise in decibels) of 1 EPNdB during a transitional period expiring on 14 June 2020 and with a cumulative margin of less than 10 EPNdB after the end of that transitional period.*
- *Operating restriction* — a noise-related action limiting or reducing the operational capacity of an airport, including operating restrictions aimed at the withdrawal from operation of marginally compliant aircraft at certain airports, as well as partial operating restrictions, which apply, for example, for a specific period of time during the day or only for certain runways of the airport.
- *Noise certificate* — document issued by a competent authority attesting compliance with the applicable noise certification standards.' [34]

LEGISLATION SPECIFIC TO AIRCRAFT ACCESS IN DIFFERENT NOISE CATEGORIES

The International Civil Aviation Organisation (ICAO) is the body responsible for aircraft certification, which has set increasingly restrictive standards, *chapters*, with regard to aircraft noise emissions. These chapters set maximum acceptable noise levels for different aircraft under specific test conditions.

Om No 152/558/1119/532-2008 approving the Guide on 'Adoption of limit values and their application when drawing up action plans, for indicators L (zsn) and L (night), in the case of road traffic noise on major roads and agglomerations, rail traffic on major railways and agglomerations, air traffic at large and/or urban airports and for noise produced in the areas of agglomerations where industrial activities are carried out', provided for in Annex 1 to Emergency Order No 84/2006, with Integrated Pollution Control and Control Act No 152/2005.

Limit values for the Lzsn and Ln (night) indicators adopted in accordance with Article 1 of [34] for *Chapter 4 (until 2020)*Tabel 3 are presented.

Table 3 Limit values of Lzsn and Ln indicators according to Regulation 598/2014

L_{zsn} (dB (A))			**L_n (dB (A))**		
Noise sources	Targets to be achieved for the maximum allowed values for the year 2012	Maximum permitted values	Noise sources	Targets to be achieved for the maximum allowed values for 2012	Maximum permitted values
Airports	65	70	Airports	50	60

The criteria for determining quiet zones in an agglomeration based on the limit value of the Lzsn indicator and the minimum surface area in which this limit value is recorded for *Chapter 4 (until 2020)* are Tabel 4 presented.

Table 4 Criteria for determining quiet areas in an agglomeration according to the limit value of the Lzsn indicator and the minimum surface area according to Regulation 598/2014

Noise sources	Maximum permitted values Lzsn-dB (W)	Minimum area for which a quiet area is defined (ha)
Airports	55	4,5

If Chapter 3 issued in 1978 is taken as a reference, the previous period of *Chapter 2* aircraft corresponds to a cumulative margin of + 16 EPNdB, i.e. the sum of the three noise levels measured for aircraft certification was 16 EPNdB higher than the sum of the levels required by *Chapter 3*. similarly, the cumulative levels for *Chapter 4* are at least 10 EPNdB below *Chapter 3* and *Chapter 14* with a minimum of 17 EPNdB.

WAY OF WORKING AND RESULTS ACHIEVED

In accordance with the provisions of the Regulation, the cumulative certification margin is 8 EPNdB for a transitional period expiring on 20 June 2020 and 10 EPNdB thereafter.

As we are close to the end of the transitional period, the aircraft was selected for the limit of 10 EPNdB.

Given the large variability of aircraft acoustic characteristics, with significantly different certification margins between vessels, it was considered a working method that takes into account the acoustic characteristics of each aircraft in the traffic composition of 2018 on the basis of information provided by the AIHCB administration as well as other sources.

The calculation performed was adapted to the requirement to consider both the different emissions and the different certification margins of each individual aircraft.

The activities aimed at achieving the following objectives:

- Highlighting the beneficial effects arising from the use of increasingly quieter aircraft, with maximum noise levels manifesting on narrower surfaces — through propagation modelling and noise level mapping (Leq) for movements of aircraft of various ICAO classifications (chapter 2/3/4/14) for a landing and take-off in one hour, on runway 08R/26L — Bucharest Henri Coanda International Airport (LROP)

- Assessment of the regulated noise levels — Lzsn and Ln — and associated exposures, for the relevant scenarios in highlighting the contributions of marginally certified aircraft at Henri Coanda International Airport;
- Obtaining an inventory of all MMC aircraft with access to AIHCB and the companies to which they belong, with the related noise certification characteristics;
- Strategic differentiated noise mapping for AIHCB, in the following situations:
  - Noise mapping for total traffic for 2018;
  - Chartering for the exclusive traffic of aircraft with MMC;
  - Chartering for remaining traffic in the possible restriction of all aircraft.
- Assessment of the differences in noise levels between the two situations, quantifying the excess noise level due to the existence of *aircraft with MMC*;
- Assessment of the number of people exposed and the differences corresponding to the two situations at the intervals of typical noise levels in accordance with Government Decision No 321/2005.

PROCESSING OF RELEVANT AIRPORT TRAFFIC DATABASES AT THE LEVEL OF 2018

On the basis of the primary data provided by representatives of CNAB — Henri Coandă International Airport (AIHCB), the summary data from the following tables have been obtained, useful both for the assessment and distribution of noise emissions and for the analysis of modelling results.

AIHCB air traffic summary for 2018 is given inTabel 5.

Table 5 Summary of AIHCB air traffic for 2018 — breakdown by month

Reference number	Month	Movements	[%] of 20118
1	January	8740	7.11
2	February	8029	6.53
3	March	9390	7.63
4	April	10062	8.18
5	May	10616	8.63
6	June	10980	8.93
7	July	12035	9.79
8	August	12048	9.80
9	September	11363	9.24
10	October	10866	8.83
11	November	9548	7.76
12	December	9314	7.57

A summary of AIHCB air traffic — with breakdown by ICAO & MTOW & M JCUM$_{chapters}$ is presented in Tabel 6 andTabel 7.

Table 6 Number of aircraft movements by AIHCB in 2018 — breakdown by ICAO chapter

ICAO Chapter	Number of aircraft movements in 2018
N/A	14
Other	7312

14	22
11	4
10	28
4	78241
6	4
8	40
3	37326
OVERALL	122991

Table 7 Number of aircraft movements Chapter 3 ICAO — AIHCB 2018

Aircraft characteristics	Number of aircraft movements in 2018	
Chapter 3 ICAO, MTOW < 34	530	TOTAL 37326: (all aircraft with noise emission certificates)
Chapter 3 ICAO, MTOW >= 34, M_{JCUM}< 10 EPNdB (63-378)	3216	
Chapter 3 ICAO, MTOW > = 34, M_{JCUM}>10 EPNdB	33580	

Estimation of the environmental implications of aircraft corresponding to the 4 ICAO chapters

In order to estimate the environmental implications of aircraft corresponding to the 4 chapters and why the noise abatement at source is very important, Figure 6.4, Figure 6.5, Figure 6.6, Figure 6.7 (Plants 1, 2, 3, 4) include assessments of noise levels for the parameter Leq for a landing and one take-off of an aircraft in each *Chapter* (with the same take-off mass), namely:

- **Plansa 1:**Noise map for parameter Leq, corresponding to an aircraft landing and take-off from Cap. 2, for one hour in one hour.
- **Plansa 2:**Noise map for parameter Leq, corresponding to an aircraft landing and take-off from Cap. 3, for one hour in one hour.
- **Plansa 3:**Noise map for parameter Leq, corresponding to an aircraft landing and take-off from Cap. 4, for one hour in one hour.
- **Plansa 4:**Noise map for parameter Leq, corresponding to an aircraft landing and take-off from Cap. 14, for one hour in one hour.

The areas included within each curve, for the four chapters, corresponding to the indicated sound exposure levels L_{AE}, or the Leq level at one landing and one take-off in one hour, for an aircraft of the same mass but corresponding to the specified chapters, Tabel 8 are assessed for comparison.

Table 8 Areas within specified ICAO curves

Leq/L_{AE} (DB (A))	Cap. 2 Area [km^2]	Cap. 3 Area [km^2]	Cap. 4 Area [km^2]	Area Cap. 14 [km^2]
> 45/80.6	149.6	59.3	30.8	19.0
> 50/85.6	63.1	21.8	10.7	6.6
> 55/90.6	23.3	7.5	4.0	2.5
> 60/95.6	8.0	2.9	1.5	1.0
> 65/100.6	3.1	1.1	0.6	0.4
> 70/105.6	1.1	0.5	0.3	0.2

Assessment of regulated noise levels — Lzsn and Ln — and associated exposures

Strategic differentiated noise mapping for AIHCB was carried out for the following scenarios, considering the relevant scenarios in highlighting the contributions of marginally certified aircraft at Henri Coanda International Airport:

- Noise mapping for total traffic for 2018;

- Chartering for the exclusive traffic of aircraft with MMC;
- Chartering for remaining traffic in the possible restriction of all aircraft.

The results are presented in the figures (s) at the end of the current chapter, representing:

- ***Plate 5:***Comparative presentation of the areas included in the 45 dB (A) curve for aircraft of the same maximum take-off mass in the four chapters
- ***Plate 6:***Total traffic noise map for parameter Lzsn
- ***Plate 7:***Total traffic noise map for parameter Ln
- ***Plate 8:***Noise map of MMC aircraft, for parameter Lzsn
- ***Plate 9:***Noise map of MMC aircraft, for parameter Ln
- ***Plate 10:***Total traffic noise map excluding MMC, for parameter Lzsn
- ***Plate 11:***Total traffic noise map excluding MMC, for parameter Ln
- ***Plate 12:***Comparison of 45 dB contour areas between total and non-MMC traffic for parameter Ln.

The scenarios were selected in order to highlight the contribution of MMC aircraft to the noise levels (Lzsn and Ln) for traffic at Henri Coanda International Airport Bucharest and the associated regulatory exposure indicators.

Estimated number of people, in hundreds, in dwellings exposed to each of the Lzsn indicator ranges, in dB, at 4 m above ground level: 55-59, 60-64, 70-74, > 75 dB, for total traffic, traffic without marginally certified aircraft and input from marginally certified aircraft (MMC) and are presented inTabel 9.

Table 9 Number of persons, expressed in hundreds, under the conditions described, in the case of traffic without MMC aircraft and the contribution of aircraft with MMC

Lzsn range values	For total traffic (hundreds)	For traffic without MMC (hundreds)	MMC input (hundreds)
Persons 55-59	104,18	100,58	3,60
Persons 60-64	4,16	3,95	0,21
Persons 65-69	0,89	0,84	0,05
Persons 70-74	0,00	0,00	0,00
Persons in the range > 75	0,00	0,00	0,00

Estimated number of people, in hundreds, in dwellings exposed to each of the values ranges of the indicator Ln, (dB), at 4 m above ground level: 45-49, 50-54, 55-59, 60-64, 65-69, > 70 dB for total traffic, non-MMC traffic and the contribution of aircraft without MMC is presented inTabel 10.

Table 10 The estimated number of persons, in hundreds, in dwellings exposed to each of the Ln indicator ranges, in dB, at 4 m above ground level

Ln range values	For total traffic	For traffic without MMC	Contribution of MMC
Persons 45-49	123,73	121,43	2,30
Persons 50-54	37,50	35,23	2,27
Persons 55-59	1,37	1,29	0,08
Persons 60-64	0,07	0,07	0,00
Persons 65-69	0,00	0,00	0,00

Persons in the range > 70	0,00	0,00	0,00

The total area, in km², represented by Lzsn values above 55 or 75 dB, the estimated number of dwellings (in hundreds) and the estimated total number of people (in hundreds) for each of these areas is shown inTabel 11.

Table 11 Total area in km² exposed to Lzsn values above 55 and 75 dB respectively, estimated number of dwellings (in hundreds) and estimated total number of people (in hundreds) for each of these areas.

Estimated	For total traffic	For traffic without MMC	Contribution of MMC
Zone expusa to Lzsn > 55 [km^2]	55,209	53,029	2,180
Zone expusa to Lzsn > 65 [km^2]	6,052	5,763	0,289
Zone expusa to Lzsn > 75 [km^2]	1,004	0,971	0,033
People exposed to Lzsn > 55	109,24	105,37	3,84
People exposed to Lzsn > 65	0,89	0,84	0,05
People exposed to Lzsn > 75	0,00	0,00	0,00
Dwellings exposed to Lzsn > 55	42,01	40,53	1,48
Dwellings exposed to Lzsn > 65	0,34	0,32	0,02
Dwellings exposed to Lzsn > 75	0,00	0,00	0,00

CONCLUSIONS

Modelling of noise levels for the parameter Leq (for a landing and take-off of an aircraft in each ICAO *Chapter* 2/3/4/14 (with the same take-off mass on the 08R/26L AIHCB runway shows the importance to be given to the reduction of noise at source, with maximum noise levels occurring on narrower surfaces on quieter aircraft, the main aspect being that of population derailment or sleep disturbance.

With a small number of MMC aircraft movements (ICAO Chapter 3, MTOW > = 34, M JCUM <$_{10}$EPNdB) and 3216 movements of the total of 122991 recorded in 2018 on AIHCB, the modelling results are relevant to a small contribution of this category of aircraft to the regulated Lzsn and Ln equivalent noise levels and — consequently — to the associated exposures.

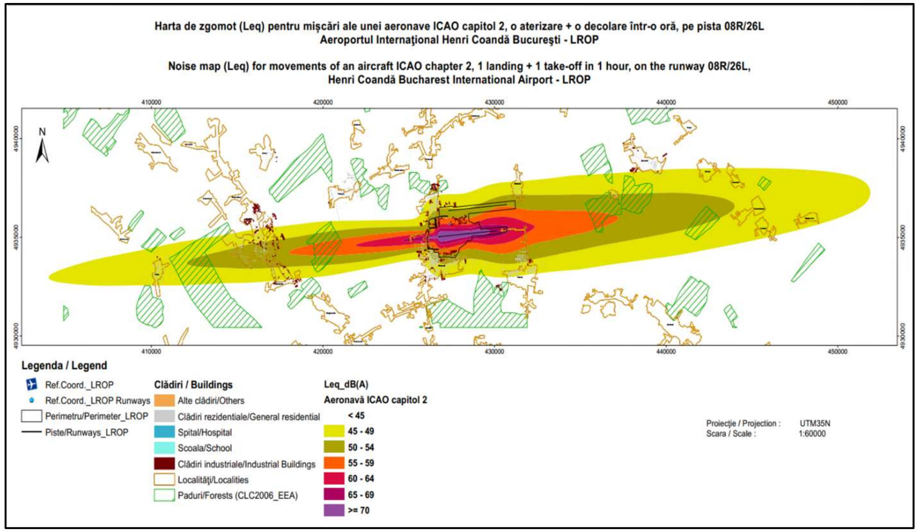

Figure 6.4 — (Planch 1) The noise map for the parameter Leq, corresponding to a landing and take-off of an aircraft from Cap. 2, over a period of one hour

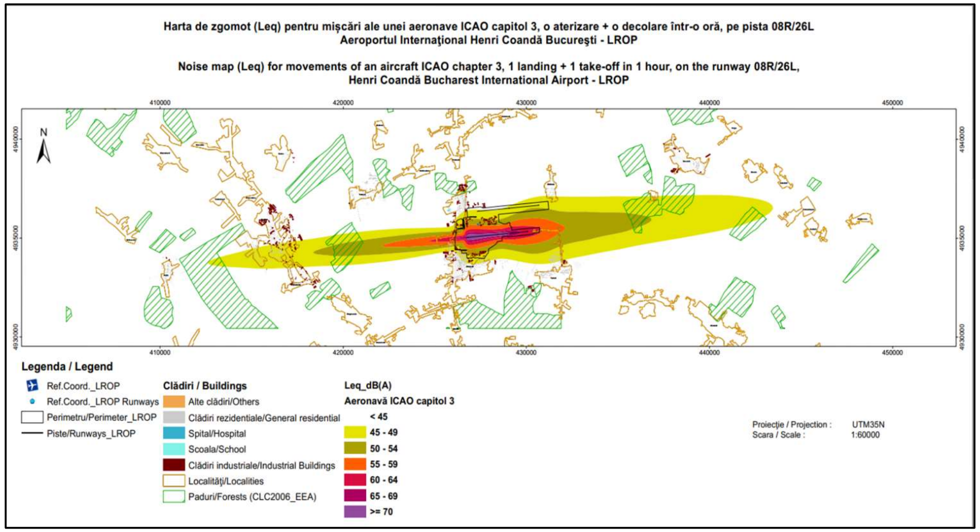

Figure 6.5 — (Planch 2) The noise map for the parameter Leq, corresponding to a landing and take-off of an aircraft from Cap. 3, over a period of one hour

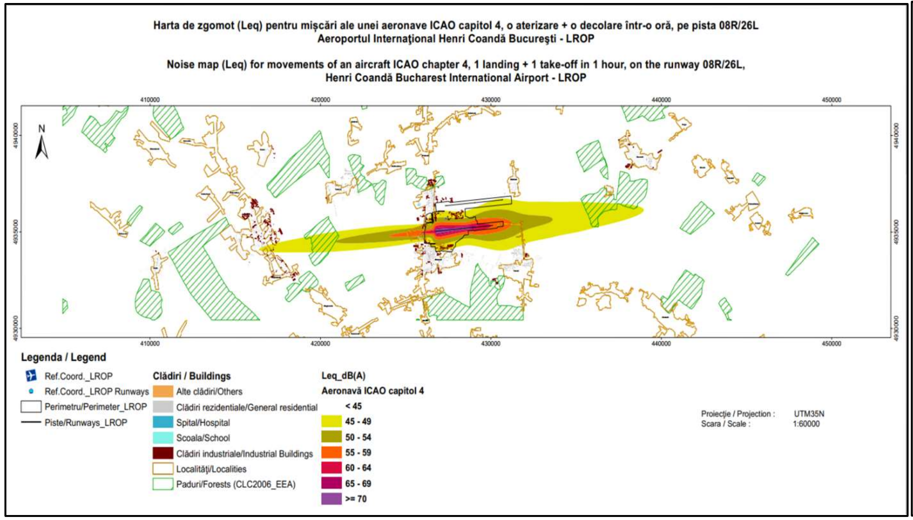

Figure 6.6 — (Planch 3) The noise map for the parameter Leq, corresponding to a landing and take-off of an aircraft from Cap. 4, over a period of one hour

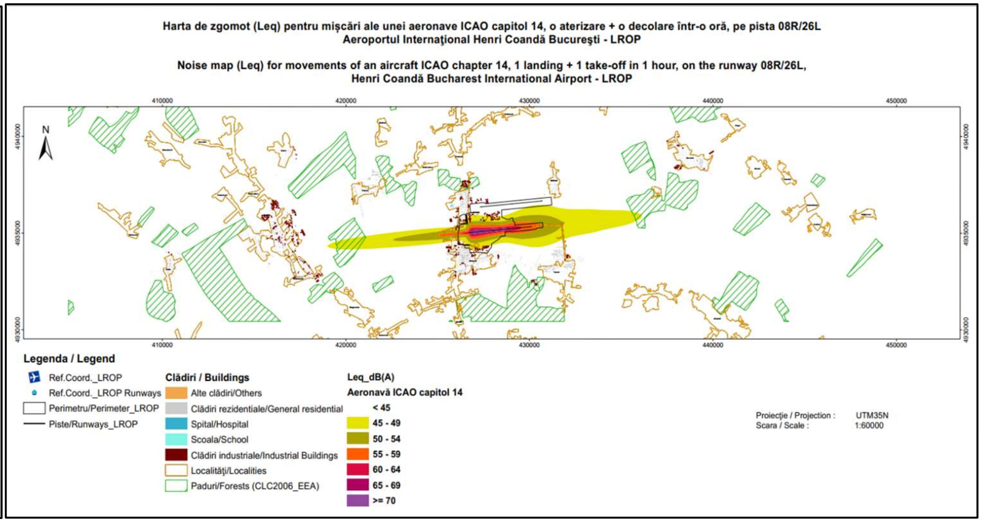

Figure 6.7 — (Planch 4) The noise map for the parameter Leq, corresponding to a landing and take-off of an aircraft from Cap. 14, over a period of one hour

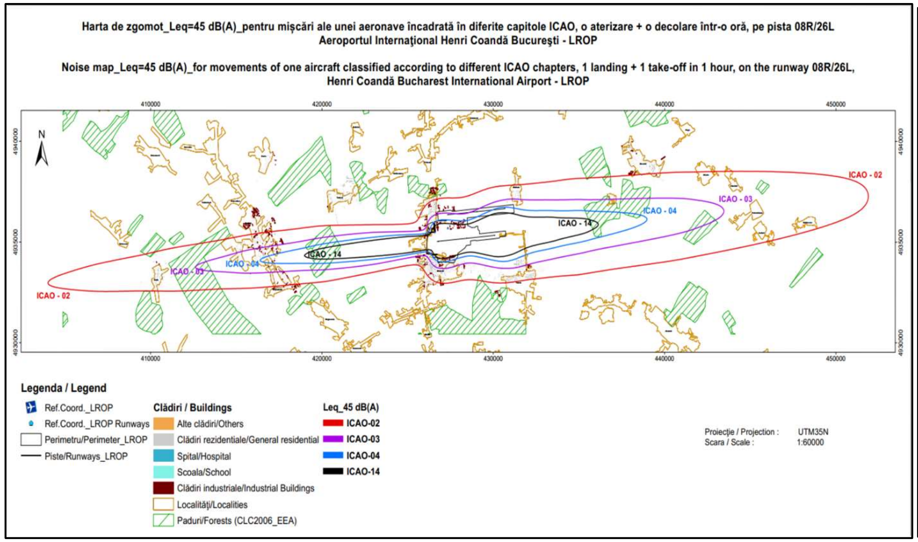

Figure 6.8 — (Plan 5) Comparative presentation of the areas included in the 45 dB (A) curve for aircraft of the same maximum take-off mass in the four chapters

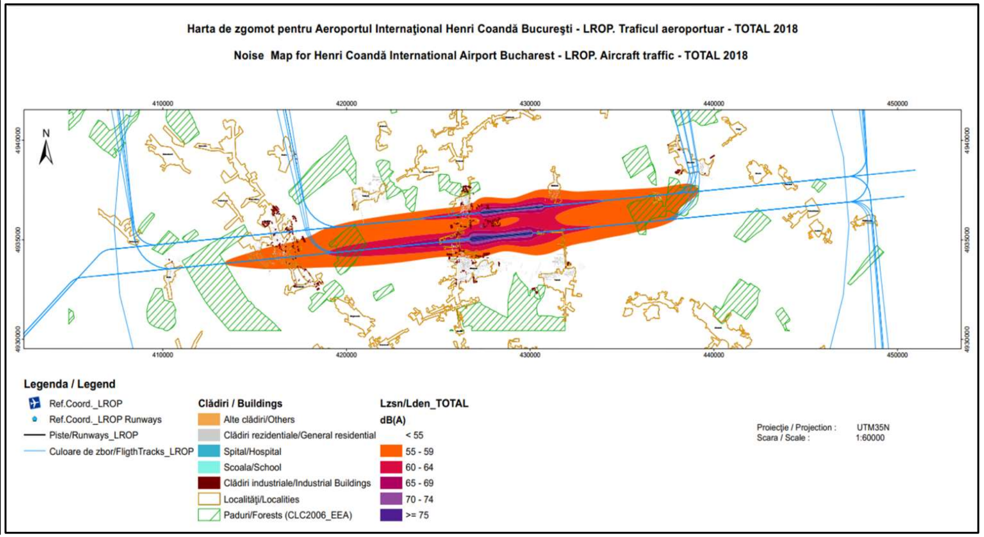

Figure 6.9 — (Plan 6) Total traffic noise map for parameter Lzsn

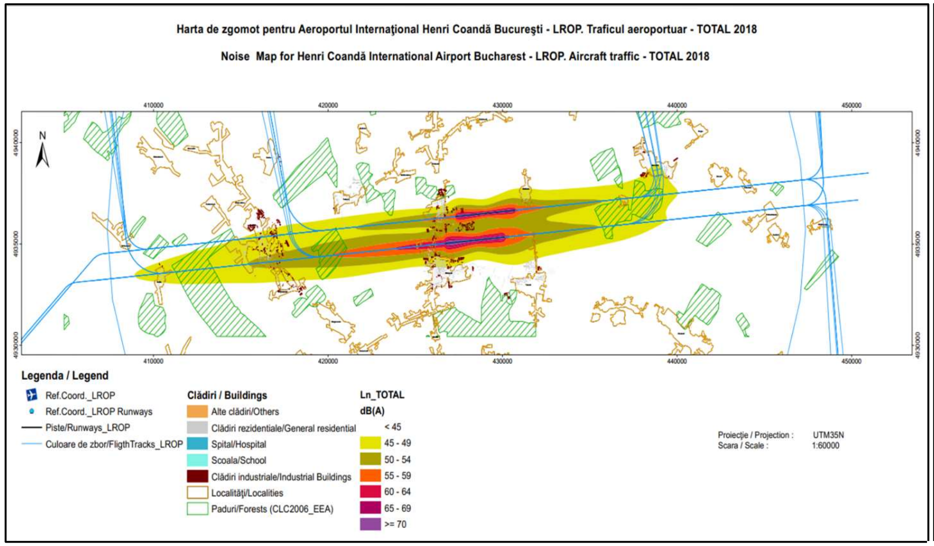

Figure 6.10 — (Plan 7) Total traffic noise map for parameter Ln

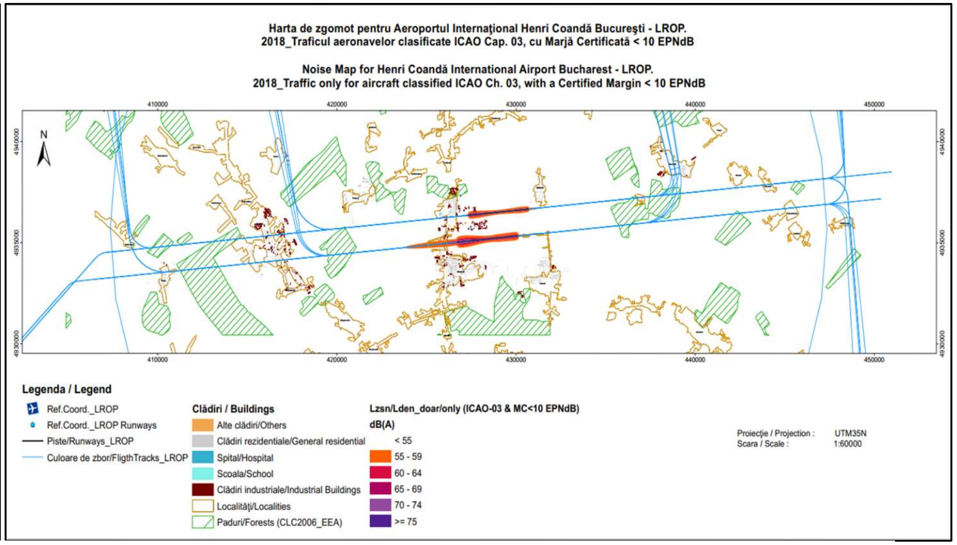

Figure 6.11 (Set 9) MMC aircraft noise map for parameter Ln

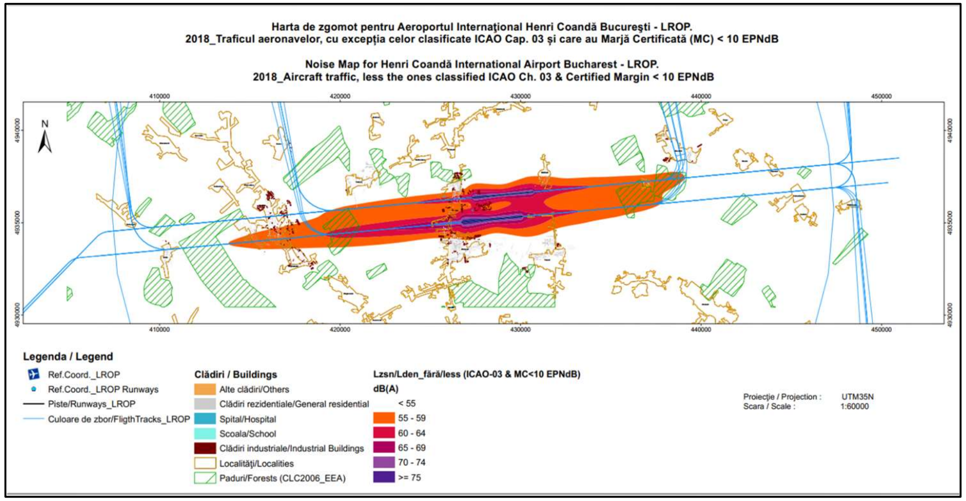

Figure 6.12 — (Planch 10) Total traffic noise map excluding MMC for parameter Lzsn

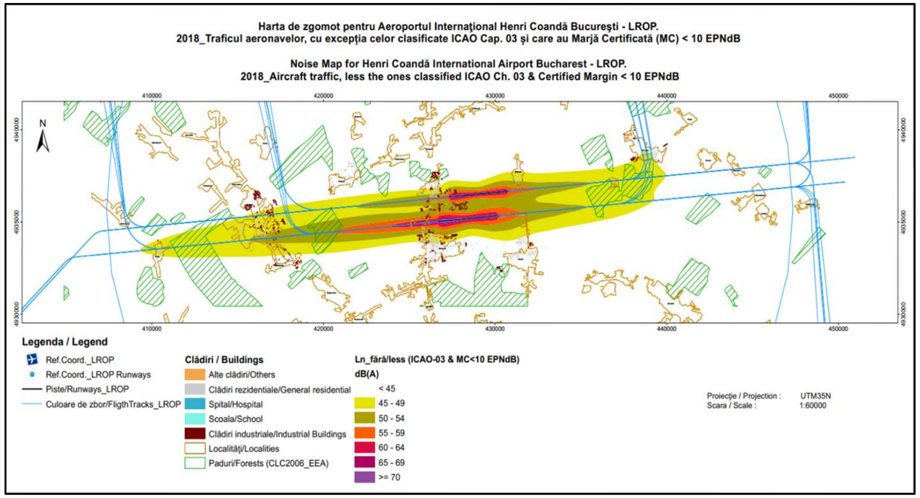

Figure 6.13 — (Planch 11) Total traffic noise map excluding MMC for parameter Ln

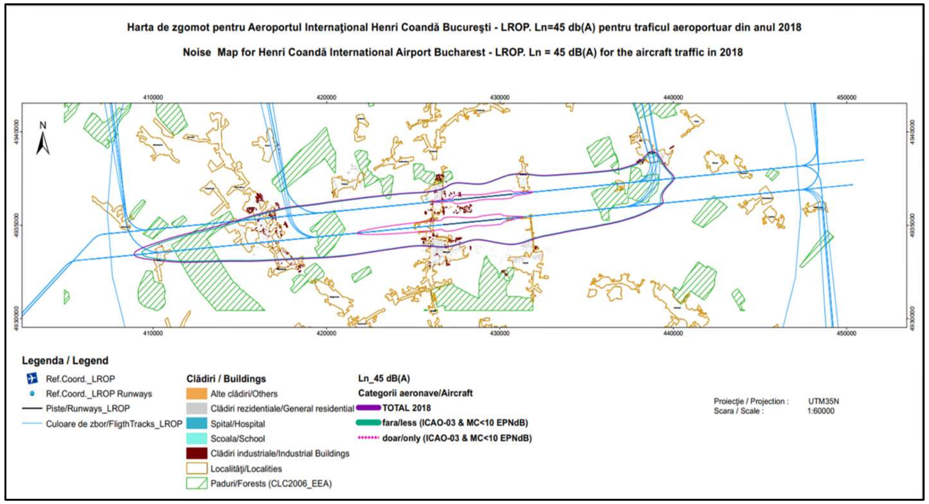

Figure 6.14 — (Plan 12) Comparison between 45 dB curves between total traffic and without MMC for parameter Ln

CHAPTER 7 — EXPERIMENTAL INVESTIGATIONS OF AIRCRAFT NOISE GENERATED ON THE GROUND AND IN THE AIR AT TAKE-OFF AND LANDING

RAISING THE DIRECTIVITY CURVE OF AN AEROPLANE TO THE GROUND

The noise produced by aeroplanes and engines has a directivity character and noise measurements must be made at points below different angles to the axis of the aeroplane or engine. These directivity characteristics are stationary on the ground under extreme operating conditions, from relates to maximum speed, with one or all engines in operation.

The measurements were carried out during the night due to the low number of landing or take-off operations and the low background noise does not influence the results of the measurements. A multi-channel procurement system 01-dB Metravib-Orchestra was used with 12 simultaneous purchasing channels. The block diagram of the measurement chain is shown inFigura 7.3..

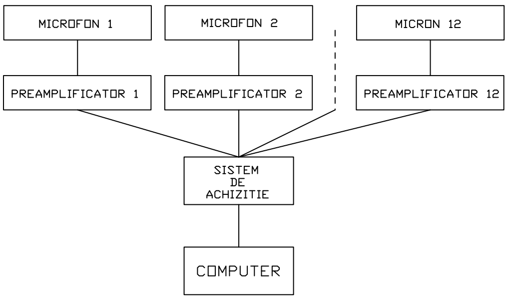

Figure 7.3 Directivity curve block diagram

Figure 7.4 Orchestra Purchasing System

Figure 7.3 shows the block diagram of the measurement chain used to upgrade the ground directivity characteristics containing 12 GRAS microphones, type 40AE, Orchestra — 12 canale- SONY EX-IF10D acquisition system, a calibrator B & K type 4231 and a laptop DELL — Latitude E6510.

A picture of the acquisition coat of ORCHESTRA-dB with the 12 purchasing channels distributed on the 3 modules and an analogue module is detailed in Figure 7.2.

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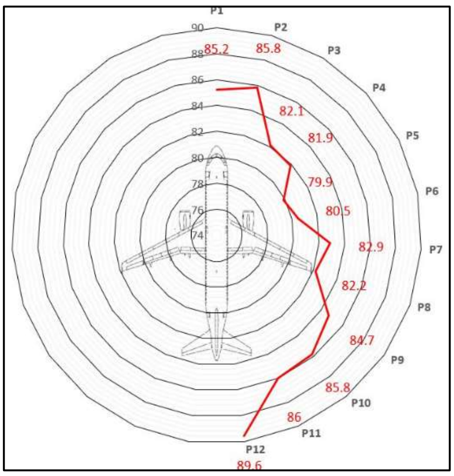

Figure 7.5 Directivity curve for sound pressure level values in dB (A) for a Boeing aeroplane at idle

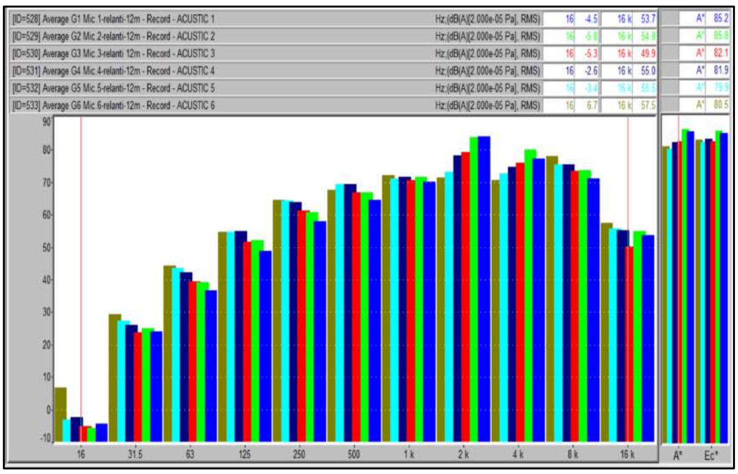

Figure 7.6 Spectrograms of noise (sound pressure level, dBA) at idle positions.1,2,3,4,5,6

Professional software used for the further processing of acoustic signals in the temporal or spectral domain, recorded digitally in the memory of the notebook computer, is based on dB — FA welded technology.

The microphone positions are approximately 24 m away from the dummy centre of the aeroplane at a height of 1.5 m from the surface of the earth, as shown in Figure 7.5.

In Figure 7.6 and Figure 7.7 the noise spectrograms recorded at the 12 measurement points (1,2,3,4,5,6) and (points 7,8,9,10,11,12) respectively are reproduced. The frequency spectra are in the 1/1 octave bands and the last column shows the overall values on the A weighting curve (dBA).

In Figure 7.7 the noise spectrograms recorded in points 7,8,9,10,11,12 are reproduced. The frequency spectra are in the 1/1 octave bands and the last column shows the overall values on the A weighting curve (dBA).

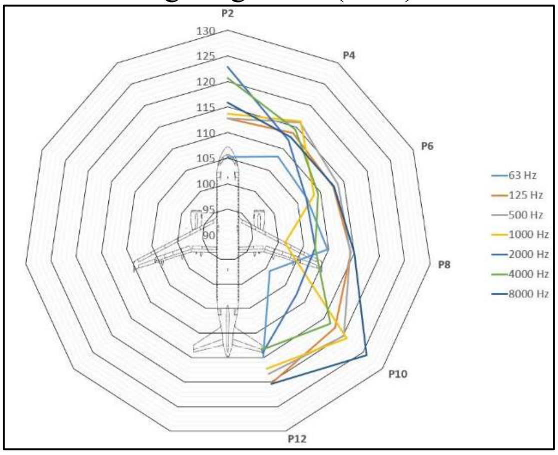

Figure 7.8 Directivity curve for sound pressure level values in dB (A), for a Boeing aeroplane, at idle, for maximum speed

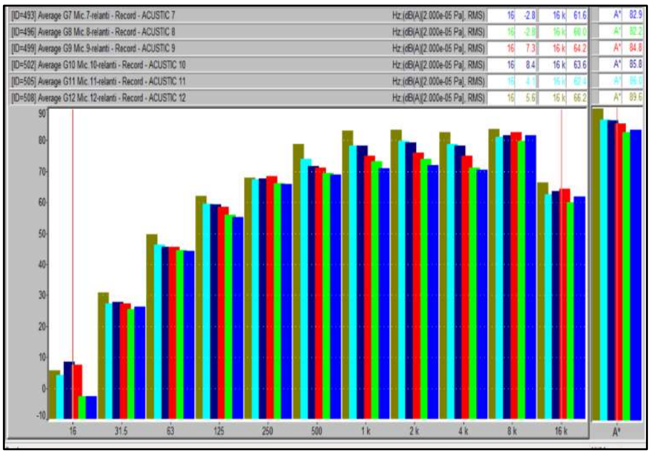

Figure 7.7 Spectrograms of noise (sound pressure level, dBA, at idle at positions 7,8,9,10,11,12

In Figure 7.8, the directivity curve is shown for sound pressure level values in dB (A) for a Boeing aeroplane, at maximum speed, at a distance of 24 m from the imaginary centre of the aeroplane, at the centre frequencies of the frequency bands.

AIRCRAFT TAKE-OFF NOISE DETERMINATIONS

Measurements of take-off and landing noise were carried out at points along the runway axis at Otopeni Airport outside the airport towards Tunari. They are shown on the map of the airport and its surroundings, as shown in Figure 7.9.

Figure 7.9 Points 1 and 2 where take-off noise measurements were made and aircraft landing respectively

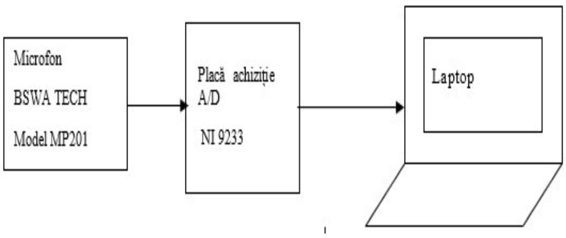

Figure 7.10 Noise measurement chain block scheme

Figure 7.10 shows the block diagram of the measurement chain of the sound pressure levels containing:

- a condenser microphone (or sound-level meter B & K 2.)
- purchase plate A/D — NI 9233 Type 4231
- laptop DELL;
- acoustic calibrator B & K.

Noise measurements consisted of measuring and recording sound pressure signals from take-off, passing through the measuring station and removing it from it. Analogue signals from the output of the microphone were inserted into a purchase plate and digitised signals from the output were stored in the memory of a Dell laptop.

Further processing of signals in the laboratory was carried out with a specialised dBFA-Metravib programme.

The sampling frequency of 50.000 Hz used for the acquisition of acoustic signals shall cover sound measurements in the audio domain to avoid folding and processing errors.

Prior to the start of the noise measurements and even during measurements, the measurement system has been calibrated by means of an acoustic calibrator B & K type 4231 which generates a standard signal of 94 dB or 114 dB at a frequency of 1 000 Hz.

The time domain and frequency domain analysis shall contain the following aspects:

- recording the timing of sound pressure signals during the optimal take-off time, representing the instantaneous value of this quantity expressed in units of pressure, Pa.
- the elevation of spectrograms in the range between 16 Hz and 16 kHz enabling the identification of spectral amplitudes of sound pressure levels and sound pressure levels in the frequency range from 10 Hz to 20 kHz on the A weighting curve, expressed in dBA.

The take-off noise measurements were carried out on 15 June 2019 at 22.

The time records for each take-off started from the visual moment when the aeroplane was picked up from the runway and when the aeroplane departed from the position of the measuring site, significantly reducing its noise.

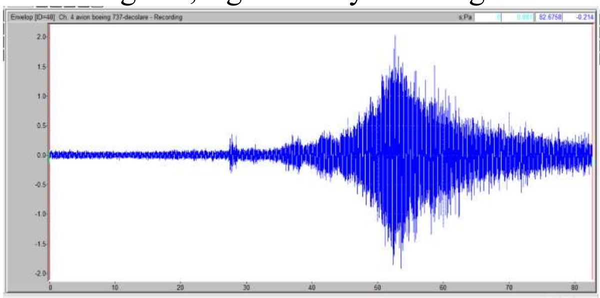

Figure 7.11 Time change in sound pressure (Pa) of the take-off noise of aeroplane Boeing 737

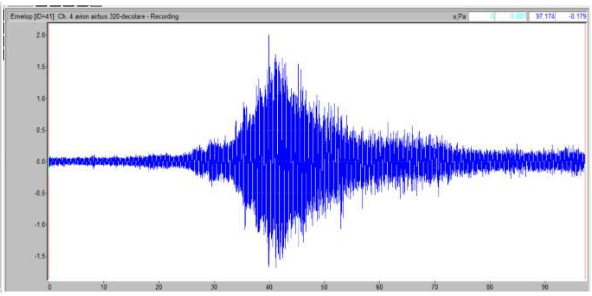

Figure 7.12 Time change in the sound pressure (Pa) of the airplane noise take-off noise 320

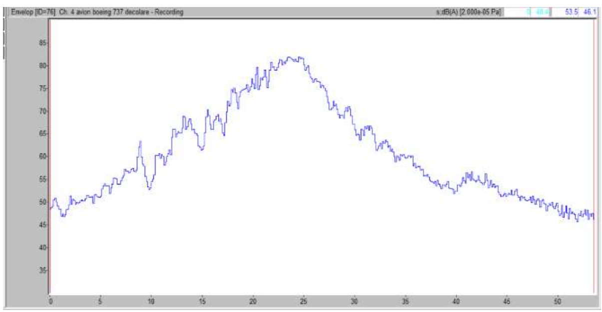

Figure 7.13 Time variation of sound pressure level (dBA), take-off noise of Boeing 737 aeroplane

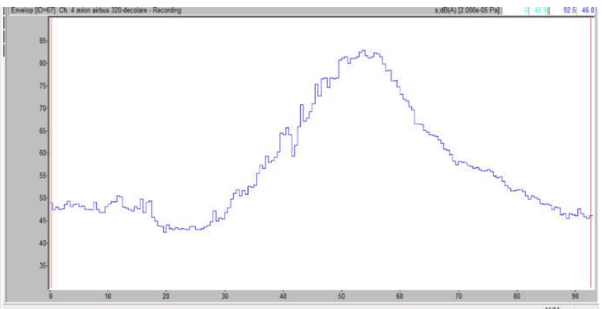

Figure 7.14 Time variation of sound pressure level (dBA), take-off noise of Airbus aeroplane noise 320

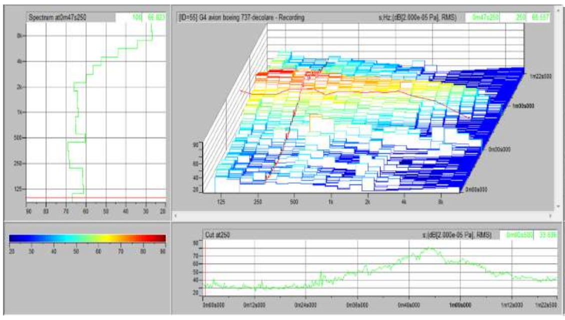

Figure 7.15 Take-off Boeing 737 noise cascading sonogram (dB)

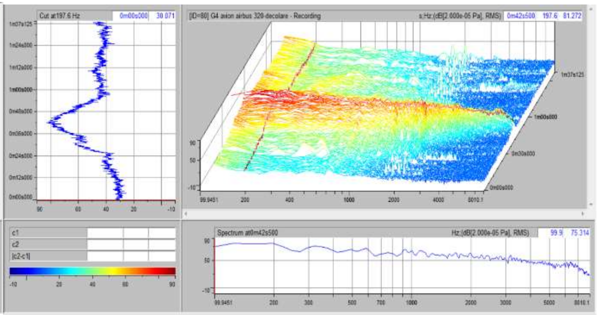

Figure 7.16 Take-off Airbus 320 noise cascading sonogram (dB)

AIRCRAFT LANDING NOISE DETERMINATIONS

In the following charts, the landing noise assessment of a Boeing 737 aircraft is displayed throughout the landing visualisation as follows:

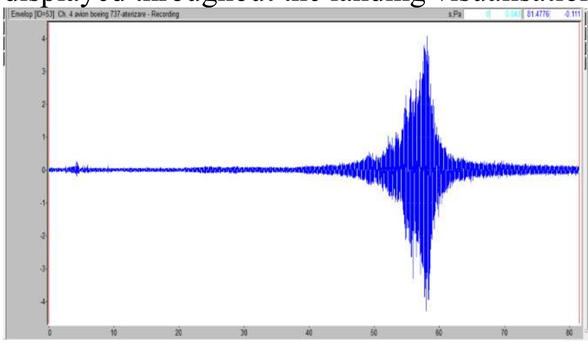

Figure 7.17 Time change in sound pressure (Pa) of Boeing 737 aeroplane noise upon landing

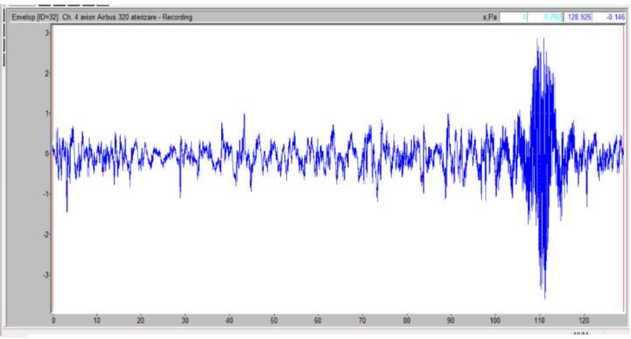

Figure 7.18 Time change in sound pressure (Pa) of Airbus 320 aircraft noise upon landing

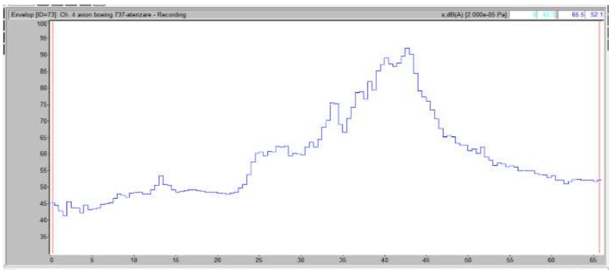

Figure 7.19 Time variation in sound pressure level (dBA) of aircraft noise Boeing 737, when landing

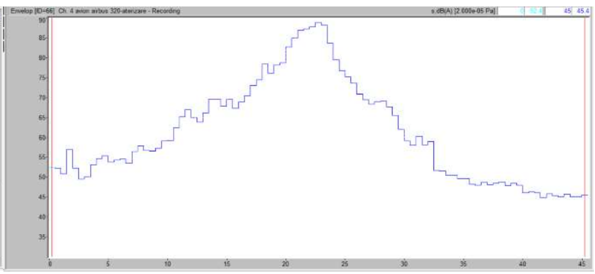

Figure 7.20 Time variation in sound pressure level (dBA) of Airbus 320 aircraft noise upon landing

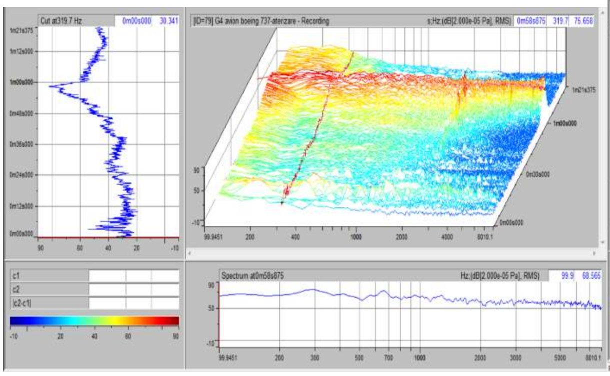

Figure 7.21 Landing Boeing 737 noise cascading sonogram (dB)

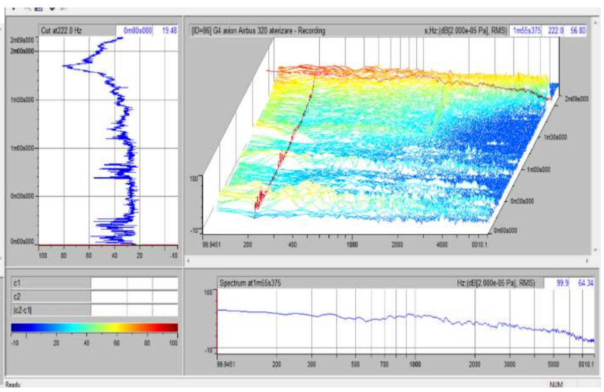

Figure 7.22 Airbus 320 landing noise cascading sonogram (dB)

CHAPTER 8 — CONCLUSIONS

ORIGINAL CONTRIBUTIONS

1. The paper summarises the acoustic quantities and their specificities in the assessment of airport noise, as well as modern analogue and numerical measurement chains in the processing of noise signals.
2. Strategic noise mapping is an activity to be carried out on a regular basis, at least once every 5 years, in accordance with the European legislation transposed into the Romanian legislation. Chapter 5 sets out the constraints limiting the overall capacity of an airport, one of which is environmental capacity, in which the noise environmental capacity is an important component. This paper describes an innovative way of working by which, on the basis of the results of the strategic mapping, the noise environmental capacity of an airport is calculated.
3. The calculation relationships on how to assess the possible air traffic multiplication constant are an own contribution to the development of this work. The conservative approach to the calculation of the traffic multiplication constant K using an additional constant c = 3 is an own decision to ensure compliance with the limit even in an additional 100 % change in traffic volume. In application of Regulation 598/2014, the multiplication constant K also indicates a measure of the degree of permissiveness of aircraft with MMC.
4. The approach outlined, by introducing an environmental capacity in the way described above, can also be applied to other noise sources as specified in the legislation, namely for road traffic, rail traffic.
5. The noise environmental capacity may be introduced in the legislation on strategic noise mapping in order to obtain additional information from this activity. If this is positive, the significance is that there are reservations about traffic growth, and if negative, restrictive or/and noise reduction measures are required.
6. In Chapter 6, an analysis of the situation of an *airport*was carried out, with more than 50 000 civil aircraft movements per year. Contributions to noise in the vicinity of an airport were highlighted for categories of aircraft belonging to different *chapters*, which highlight the importance of reducing noise levels *at source*.
7. Building on the obligations of an EU State to introduce into national law the provisions of Regulation 598/2014, Chapter 6 proposed as a novelty a working methodology quantifying the contributions of marginally certified aircraft to the overall noise exposure of the vicinity of a large airport. The advantage of this working method is that it provides concrete and precise information justifying possible operating restrictions on marginally certified aircraft, as a last step within a *balanced approach*.
8. The technique proposed and addressed by the author in measuring the directivity of an aeroplane proposed in Chapter 7 on the ground as well as the noise assessment at the take-off and landing of an aeroplane may serve as a reference for similar experiments in the study of the acoustic radiation characteristics of an aeroplane.

   Recording the sonograms in the cascade used by the author by successively depicting the spectrogram of noise generated over time at a point of observation is a modern, useful and convenient method of assessing non-statistical acoustic radiation. The measurement methods used in the work use complex approaches to numerical measurement and processing of signals, using advanced, professional programmes that are also used throughout the thesis.

FUTURE RESEARCH DIRECTIONS

1. Directive 2002/49/EC envisages separate strategic noise charts for 4 main sources of environmental noise: road traffic, rail traffic, air traffic and industrial activity. There are

often important areas in the vicinity of an airport characterised by noise interference situations from two or more sources defined for the purposes of the above Directive.

As examples: road traffic (zone Otopeni — airport + DN1, airport + DJ200B, zone Băneasa — airport + DN1, airport + Bvd. Pipera), industrial air traffic (Băneasa area — airport + Băneasa industrial area).An important research direction is the analysis of noise in these interfering areas where the exposure of the population is multiple.

2. Strategic noise mapping shall be performed for sources represented by typical aircraft operations (movements): landings, take-offs, overflights. A number of noise-generating activities take place on the territory of the airport, which are not taken into account in noise mapping, and which transform the airport's premises into a noise-generating area, which must be taken into account, especially where inhabited areas have extended to relatively short distances from the airport's territory.

   One direction of research is the analysis of noise generated by sources not taken into account in the strategic noise mapping (aircraft movements between disembarkation/embarkation area and runway ends, engine test stands, auxiliary power units (APUs), repair activities, runway maintenance activities, etc.) and the establishment of an appropriate strategy to reduce noise levels.

3. Given that dose-effect studies show that derance in humans starts from noise levels Leq = 40... 45 dBA, research on the optimisation of flight paths should also be carried out beyond the minimum limits for noise contours, i.e. 45 dBA for Lnight and 55 dBA for Lday-evening, laid down in Directive 2002/49/EC.

   Optimisation would be achieved by selecting lanes that bypass large population areas for areas outside the mandatory mapping area.

4. A direction of research of significant utility is the acoustic zoning of the area in the vicinity of each airport on the basis of contributions from sources interfering in different areas of this area, as defined in point 1. In this way, the municipal administration belonging to it would have a criterion relating to the use of the territory, indicating the type of buildings that may be built in different areas of the area under consideration, on the basis of their different noise sensitivity.

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ANNEX A — PHD SCIENCE PUBLICATIONS AND COMMUNITIES

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