Noise contour calculation from measured data
Runway 03/21 Lisbon Airport
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Abstract: Noise is nowadays the most important environmental affection in the airport surroundings. As the air transport is growing continuously, the number of planes overflying the cities is also increasing and the noise problem doesn’t seem to decrease in the next years. Lisbon airport is an exceptional example of this problem as it is located into the city and its operational routes pass over very populated areas. To measure the noise impact nowadays the most used tool are the noise contours over a map around the airport. Those noise contours are calculated from flight reports and data from the aircraft manufacturers. This work tries to propose a method to obtain the noise contours for the runway 03/21 from Lisbon airport from measures instead of the data given by the airport and the different aircraft manufacturers. Not 24 hour measures are needed to obtain the noise contours with this method due to the definition of the “typical hours”, average hours depending on the aircraft type and the part of the day. As part of future study a proposal from the author (Multiple threshold), of defining two thresholds in the 03 runway, one for D and E type planes and the other one for C or lower type planes, is described as an idea for decrease the noise levels in the approximation maneuver to that runway.

Keywords: Noise, Noise contour, Lisbon airport, Multiple threshold

1. INTRODUCTION

Acoustic contamination is nowadays an inherent phenomenon to every urban area, and constitutes an ambient factor of singular impact over the life quality of their inhabitants. In a great number of instances, aircraft noise simply merges into the urban din, a cacophony of buses, trucks, motorcycles, automobiles and construction noise. However, in locations closer to airports and aircraft flight tracks, aircraft noise becomes more of a concern (source: FAA, 1985 [1]).

Airports with noise problems and air authorities are introducing operational restrictions and taxes to the most noisiness airplanes and reducing the operation of the airports in determined parts of the day. Trying to coordinate all these policies from the different airports, ICAO developed the “Balance Approach” in 2004 (Doc 9829, AN/451) [2] and revised it in 2007. This document tries to address aircraft noise problems at individual airports in an environmentally responsible way and to achieve the maximum environmental benefit most cost-effectively.

One of the first steps when analyzing the noise problem around an airport is to create a noise contour map to have a clear idea of the impact over the different parts of the city of the noise produced by the airplanes. Nowadays these noise contours are calculated by computer programs such as INM or ANCON [3] from previous flight reports.

Adapting the recommendations given by ICAO, ECAC, SAE1 and other works about constructing noise contours, this document tries to achieve a method to calculate noise contours around airports from measures made in the street. To test the availability of the method, a study will be done for the runway 03/21 from Lisbon airport in its west side.

In section 2 the noise indicators are exposed and there is a summary of the recommended techniques to calculate the noise contours and some works related to measured noise contours are shown. In section 3 the proposed method is described and the noise surface is calculated for the area of study. In section 4 the “multiple threshold” proposal is described and, at last, section 5 is dedicated to the conclusions.

2. NOISE INDICATORS & NOISE CONTOURS

2.1. NOISE INDICATORS

The Equivalent Continuous Sound level (Leq) is the most common used indicator in ambient acoustic because is representative of the relevant characteristics of the ambient sound (in audible perception terms), is relevant for all the

1 “Circ.205 ICAO”[4], “Doc.29 ECAC”[5], “SAE-AIR-1845 [6]”
possible situations (noise types), and for its easy implementation with a non-difficult calculus behind. As it is so common, it also allows an efficient communication between legislators, technicians and general public (Coelho & Ferreira 2009 [7]). It is well known that the magnitude of L\text{Aeq} correlates well with the effects of noise on any kind of human activity (Source: Zaporozhetz, 1998 [8]).

Defined in the “Norma Portuguesa NP-1730” as the constant sound pressure level that integrated in the considered time interval (T) presents the same sound energy that the signal in analysis variant in time:

\[
L_{\text{Aeq}} = 10 \log_{10} \left[ \frac{1}{T} \int_{0}^{T} L_{\text{Ap}}(t) \frac{10}{10} \, dt \right] \quad (1)
\]

Where L\text{Ap} in dB (A) is the sound pressure level with the “A” adjustment.

The Sound Exposure Level is defined as the constant noise level during one second that contains the same acoustic energy in “A” weighted than the original sound in a determined time interval (Ref [7]).

\[
SEL = 10 \log_{10} \left[ \frac{1}{t_2-t_1} \int_{t_0}^{t_2} \frac{p^2(t)}{p_0^2} \, dt \right] \quad (2)
\]

Where \(t_2-t_1\) is the interval of the noise event and \(t_0\) is the reference time (one second), \(p\) is the measured pressure and \(p_0\) is the reference pressure (20\(\mu\)Pa).

This indicator (SEL) characterizes the energy of a single noise event, for example, the flyover of a plane. It is possible to calculate the equivalent continuous sound level (L\text{Aeq}) for a total period (T) with (A) adjustment from the SEL of each acoustic event in that period. The sound exposure level for each event is weighted for the time-of-day and in some countries time-of-week in accordance with the national method. The summation is defined as follows (Ref [5]).

\[
L_{\text{Aeq},W} = 10 \log_{10} \left[ \frac{1}{T} \sum_{j=1}^{N} W_{\text{SEL}_j} 10^{\frac{\text{SEL}_j}{10}} \right] \quad (3)
\]

Where

- \(SE\text{L}_j\) is the sound exposure level from the \(j^{th}\) aircraft operation out of \(N\),
- \(W\) is the weighting factor depending on the time-of-day and in some countries time-of-week,
- \(T\) is the reference time for L\text{Aeq} in seconds.

The L\text{den} is a 24h noise indicator based on the L\text{Aeq} but with a a penalty of 10 dB during night time (23:00-07:00) and 5 dB during the evening. (20:00-23:00) (Decreto lei 146/2006 [10]).

\[
L_{\text{den}} = 10 \log_{10} \left[ \frac{1}{24} \sum_{i=1}^{24} 10^{\frac{L_{\text{day}}(i)}{10} + \frac{1}{2} 10^{\frac{L_{\text{eve}}(i)+5}{10}}} \right] \quad (4)
\]

Where:

- \(L_{\text{den}}\): The indicator that represents the noise level during all the day
- \(L_{\text{day}}\): L\text{Aeq},1h for “Typical hour day”
- \(L_{\text{eve}}\): L\text{Aeq},1h for “Typical hour evening”
- \(L_{\text{night}}\): L\text{Aeq},1h for “Typical hour night”

2.2. NOISE CONTOURS

Airport operations generally include different types of aeroplanes, various flight procedures and a range of operational weights (Ref [6]). Because of the large quantity of aeroplane-specific data and airport operational procedures, noise contours are needed to be calculated by computers (Ref [5]).

From the respective data on noise and performance, the aeroplanes are grouped and representative data are selected from the specifications given by the manufacturers. The calculation grid is arranged over the affected zone and the calculations of noise levels at the grid points, for the individual aeroplane movements using the SEL are made. The noise levels (SEL) at each grid point are summed or combined according to the formulation of the previous section to calculate the L\text{Aeq} with the equation (3) and then the L\text{den} values using (4).

Finally, interpolations are made between noise index values at the grid points, to locate the contours.

2.2.1 INM

The Integrated Noise Model (INM) is a computer model that evaluates aircraft noise impacts in the vicinity of airports. It is developed based on the algorithm and framework from SAE AIR 1845[6] standard, but also compatible with the ECAC Doc. 29 [5]}
and the Circ. 205 from ICAO [4]. This uses Noise-Power-Distance (NPD) data from aircraft manufacturers to estimate noise accounting for specific operation mode, thrust setting, and source-receiver geometry, acoustic directivity and other environmental factors. It was developed by the FAA and nowadays is one of the most used programs to calculate noise contours around the airports (C. Asensio, 2006 [10]).

2.3 MEASURED NOISE CONTOURS

Other works used measured data to obtain the contours. The main steps given by C. Asensio in the document “Estimation of directivity and sound power levels emitted by aircrafts during taxiing, for outdoor noise prediction purpose” (Ref 10) are the following:

- A measurement surface grid must be defined to envelope the noise source.
- The grid is used to locate microphone positions.
- Linear averaged third octave band spectra must be measured for all microphone locations.
- Averaged surface sound pressure levels can be calculated.
- Third octave bands sound power levels are obtained and can be A-weighted to obtain overall levels.

For this study, the representation of the third octave band spectra is not necessary because the objective is to measure and represent overall noise energy. In case of the methodology used by Dae Seung Cho in the document “Noise mapping using measured noise and GPS data” (Ref[11]), follow thefigure 2.1.

This method is applied, as a test, to calculate the noise in the area of the Pusan national university. They measure in 735 different points to calculate the contours by triangulating the results. The noise they are measuring is continuous so they measure once in each point and with the triangulation calculate the contour. In the case of this study, the airplane noise is not continuous and each noise event doesn’t have the same energy, so it is not possible to measure only once in each point of measure.

**Figure 2.1 Noise mapping procedures using measured noise and GPS data (Source: Dae Seung Cho, 2006)**
3. **METHOD, SURFACE CALCULATION & ANALYSIS**

3.1. LISBON AIRPORT

Lisbon airport is located in Portela de Sacavém, 7 km Northwest to the city centre. In topographic terms the airport implantation area is relatively plain, placing in a height of approximately 114 meters from the sea level. It has an area of 495 hectares, with two terminals and two runways, the 03/21 (3082X45) and the 17/35 (2304X45).

The zone under the study of this work is located between the airport and the bridge “25 de Abril” under the flight track of the runway 03-21. When a runway is in use, the direction of the landings and take-offs depends on the wind direction and speed. As it is a benefit for the operations near ground to have front wind, the 03 runway is used when the wind is coming from the north east (for landing and for taking-off) and the 21 is used when the wind blows from the southwest. The preferential use of this runway with calm wind conditions is the use of the 03. The planes will pass over the place of the study when taking-off using the 21 and when landing on 03.

3.2. METHOD

The proposed method is based on calculating the SEL in each point from measures made in the affected zones instead of calculating it from the information given by the different aircraft manufacturers.

The INM software uses flight reports from the airports for long therm periods to configure the contours. As measures cannot be made the 24 hr of the day, necessary for the equation (4), “typical hours” are defined in order to solve this problem. The calculus is made assuming that all the hours in each period are the “typical” one. These “typical hours” try to reflect the average movements for each period and are calculated from traffic statistics from the year 2009. It is remarkable to say that the “typical hours” are the same for landing and for taking-off.

There is a wide variety of plane types flying today in the world. Aircraft grouping is a solution to simplify the amount of data used for the calculus. In case of this work, the grouping will permit the definition of the “typical hours”. The groups are the ones defined by ICAO in its annex 14 [12] depending on the main gear wheel span and wing span. According to the different noise measured from planes with the engines on the tail, those ones will create a group called G.

The places to make the measures must have a clear view of the plane when this is overflying the city, trying not to have near buildings or trees. It also has to cover nearly all the area in study. The surface is considered symmetric to the central axis of the runway so the points non located in this line are considered twice. Other issue to take care of is the background noise that must be as low as possible because a high level of noise around the measure point increases the energy measured in the event invalidating it.

The selected points are shown in figure 3.1.

![Figure 3.1 Measure points placement](https://example.com/figure31.png)
Table 3.4 Typical hours’ calculation

<table>
<thead>
<tr>
<th></th>
<th>Percentage over total</th>
<th>“Typical hour day”</th>
<th>“Typical hour evening”</th>
<th>“Typical hour night”</th>
</tr>
</thead>
<tbody>
<tr>
<td>C type</td>
<td>67.32%</td>
<td>8</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>G type</td>
<td>11%</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>D type</td>
<td>7.2%</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

From the measures in the different points of the city the “typical hours” are configured according to the previous airplane type selection. As all the hours in each part of the day are supposed the same, the equation \((4)\) gets as shown below:

\[
L_{den} = 10 \log_{10} \left( \frac{1}{24} \left( 12 + 10^{\frac{L_{day}}{10}} + 3 \times 10^{\frac{(L_{eve}+5)}{10}} + 8 \times 10^{\frac{(L_{night}+10)}{10}} \right) \right) \tag{5}
\]

Where:

- \(L_{day}\), \(L_{eve}\) and \(L_{night}\) are the LAeq calculated with eq. \((3)\) using the plane distribution defined in the “typical hours”

Before introducing the \(L_{day}\), \(L_{eve}\) and \(L_{night}\) values in the equation \((5)\), the background noise is taked away using the following equation:

\[
LA_{eq} = 10 \log_{10} \left( \frac{L_{A_{eqm}}}{10^{\frac{L_{A_{eqm}}}{10}} - 10^{-\frac{Bgr}{10}}} \right) \tag{6}
\]

Where:

- \(LA_{eq}\): The LAeq value without background noise
- \(LA_{eqm}\): The LAeq value with background noise
- \(Bgr\): Background noise level

A summary of the process is exposed on figure 3.2.

3.3. NOISE SURFACE

According to the previously exposed method, the \(L_{den}\) noise levels are calculated in each point to obtain later the surface using a linear interpolant.

The obtained surface for the \(L_{den}\) with the proposed method is the following:
4. SELECTIVE THRESHOLDS PROPOSAL

This proposal tries to achieve a reduction in noise produced during landing maneuver. Nowadays the displaced threshold is a commonly used technique to reduce the noise in the vicinity of the airports. It consists on displacing the threshold of the runway some distance from the beginning of the pavement to separate the planes from the ground when they are overflying populated areas during landing maneuver. The displacement of the threshold is done according to the most restricted plane in performances, it means, that the rest of the planes have more runway length than they need.

The selective threshold proposal tries to reduce the noise even more by adapting the runway length to the performances of the plane that is landing. As a first step, the proposal exposed here is with only two thresholds and applied to the runway 03/21 from Lisbon airport.

Analyzing the traffic into the airport, the C or lower type aircraft suppose the 68.32% of it in the year 2006. The plane into these groups, with the longest runway length in performances for landing is the A321 which needs about 2000 meters (Airbus Airport planning [13]).

The runway 03/21 is 3805 meters long so the proposed displacement for the secondary threshold is of 1200 meters (figure 4.2). In this case, the D and E type planes use all the runway (3805 m) and the C or lower type planes use “shot” runway (2605m), which is even longer than the other runway from the airport (17/35 2304m).

The displacement of 1200m means that planes overfly 62.8 meters higher the city (figure 4.3) so a reduction of noise is produced over the populated areas in study in this document. The new noise contour is the same calculated before but displaced a distance near to 1200m (the D and E type planes continue making the same noise as before).

Some technical difficulties must be studied to check the availability of this measure. There should be different lights for both operations of the runway (shot and long), and the ILS has to be studied in deep so as to know if it is possible to have two different Glide Paths with one Localizer. Also the controllers and pilots must learn to operate with two thresholds in the same runway.
5. CONCLUSIONS

The objective of this work was to achieve a method to calculate and plot noise contours around airports from measures in the street instead calculating them with specific software using data from the aiport and aircraft manufacturers. For this, it has been used the recommendations from ICAO, ECAC and SAE for computing contour calculation and some works for measuring contour calculation.

The method proposed supposes that not many measures can be done in each point, or at least, not during the 24 hours of a day. To analyze the noise for all the day using the measures made in one part of it, “typical hours” were defined from statistics from the airport to compound average hours in operation depending on the aircraft type and part of the day. Using this information, measures were made and according to the appropriate formulation, the noise levels were calculated using the Lden noise indicator.

To test the availability of the method a study of the runway 03/21 from Lisbon airport in its west side was made. There was made 489 measures of overflying planes, more or less 50% of landing aircrafts and 50% of taking-off ones. The results show a difference between 3-5 dB(A) higher than the contours published by ANA in 2006 as it is shown in the figure below.

The calculus plane for the INM software was placed at 114m above the sea level and all the measures were made under that height. As the measures were made further to the planes, the sound levels should be lower than the ones calculated by ANA. The study takes care of the background noise, the different aircraft type, the different periods of the day. This result shows that more noise is reaching to the city than the levels predicted by ANA.

Apart from the contour calculation and analysis, the problem of noise in Lisbon is not in near or easy solution. The fact of being in the middle of the city obliges the planes to flyover it and disturb the people living or working there. There is a big list of noise measures implemented to reduce that affection to the surrounding areas of the airport (Source: NAV, 2004 [14]).

The proposal of selective thresholds shows a reduction between four to one dB(A) in the noise affection to the city. The implementation of this technique is not complex because there is not new technology involved and the landing procedures stay nearly the same. The difficulty is to develop it and teach the personal how to work in that new procedure situation.

BIBLIOGRAPHIC REFERENCES


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