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THE METHOD ADOPTED IN BRAZIL TO ASSESS NOISE NUISANCE LEVELS CAUSED BY AIRCRAFT OPERATIONS

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1. INTRODUCTION

Communities are now giving growing importance to airport noise pollution; even the media has been against air operations. As a result, airport authorities were forced to study the problem, analyse noise abatement procedures and attempt to discipline land use in Brazilian Airport environs.

Among the various kinds of industrial and urban noise, aeronautical noise has unique features. Its propagation surpasses the legal limits of the airport where it starts. The normal landing and take-off operations not only produce high intermittent noise but also don't usually have a schedule.

Jet aircraft operations have raised nuisance levels to extremes. Since the nineteen fifities complaints have encouraged studies and researches to size the problem and to find methods of minimizing it, so that the noise and nuisance levels generated by aircraft operations can be quantified.

The world nations have brought their experience of the problems to International forums like ICAO and IATA and have established basic action points to combat noise pollution caused by airports. In the last 25 years, several different measurement units have been proposed to quantify noise and nuisance levels. There is an international consensus on the methods used in measuring the noise generated by one aircraft alone; on evaluating nuisance levels, however, opinions vary. In Brazil, CECIA, in accordance with its attributions of studying and coordinating aeronautical infrastructure, uses a method based on ICAO proposed methodology. The unit adopted for calculating cumulative nuisance is called weighted noise index-WNI.

The WNI is used to generate contours of the same nuisance level for areas near the airports. Based on them, land uses can be better planed, reconciling noise and nuisance levels with the activities developed in these urban areas.

2. ASSESSMENT OF THE NUISANCE LEVEL GENERATED BY AIRCRAFT OPERATION

Noise generated by aircraft during airport operations has singular features. To begin with, for someone who is near an airport, the perceived noise will seem intermittent and irregular because this noise varies according to movement, type of aircraft and landing and take-off procedures used in that particular airport. Secondly, noise intensity derived from jet aircraft is much greater than that derived from other noise sources in the daily life of cities. Another important feature is the fact the noise source is mobile and is above earth level, most of the time, which makes noise propagation easier due to the lack of

obstacles.
Therefore, assessing airport noise isn't only assessing noise generated by each aircraft. The overall effect of noise derived from the communities of airport environs must also be taken into account. Thus, it is necessary to establish a calculation procedure to match noise data from each event; number of events under consideration; time span between the first and the last event, and many other measurable data in order to obtain a graduation for aeronautical level. This level is a function of the point were measurements are taken as well as a mesure of the listener's nuisance level. The effects of noise impact on the communities of airport environs are the main concern in this case.

2.2. THE METHOD ADOPTED IN BRAZIL

In Brazil, aeronautics noise studies and noise pollution policies are, in this phase, concerned with problem prevention. The aim to prevent the worsening of incompatible situations in some Brazilian airports, as well as to avoid new incompatibilities arising in new airports.
Thus, it was necessary to devise a nuisance level assessement method in order to generate isophonic contours for current or future situations. Moreover, the method must have a standardize reference period to establish an identity between levels measured "in loco" and forecast levels.
The method, which has been used up to now and in accordance with established requirements, is Noise Exposure Forecast – NEF, developed in 1969 by the Federal Aviation Administration – FAA. As Brazil is one of the countries to sign ICAO Annex 16, an analogous method to the Weighted Equivalent Continuous Perceived Noise Level – WECPNL introducing some of the NEF characteristics was proposed by this entity. Therefore, weights for daily and night flights were kept; the reference period was restricted to one day and seasonal adjustement was excluded. The method was also used in isophonic contour generation programs.

2.3. WNI CALCULATIONS PROCEDURES

These are the necessary data to forecast WNI at a given point in the vicinity of an airport and comprise:

I. aircraft mix in the airport;
II. average number of daily and night operations; daily operations are from 7a.m. to 10p.m. and night operations from 10p.m. to 7a.m.;
III. distribution of these movements through the various routes to and from the airport;
IV. technical data on the aircraft operating in the airport, such as:
   - take-off profile, with the average take-off weight used for each aircraft in each of the airport runways;
   - instrument landing profile for each airport runway;
   - level of effective perceived noise contour versus the distance of the observer from the aircraft, for each aircraft used.

In order to forecast WNI at a given point on earth, it is necessary to determine the levels of effective perceived noise corresponding to each of the overflights which occurs during a day of average airport operation. Considering that, for an overflight performed by a type i aircraft following route j during a k time of the day, the level of effective perceived noise L_{EPN} (i, j, k) is obtained.
This level is calculated by entering the value of the distance of the given point to route j in the L_{EPN} versus distance graph corresponding to type i aircraft.
The WNI component due to all type i aircraft, following route j during the k time of the day is given by:

$$WNI\ (i, j, k) = L_{EPN}\ (i, j, k) + \log_{10} p\ (k)\ .\ n\ (i, j, k) - 68$$

Where:

n (i, j, k) = the number of these aircraft
p (k) = a weight that is a function of the time of day. For the daily period K =1 and p(1) = 1 and for the night periods k = 2 and p(2) = 10;

The Weighted Noise Index is then obtained by the expression:

$$WNI = 10\log_{10} \sum_{i} \sum_{j} \sum_{k} \text{antilog}\left(\frac{WNI\ (i, j, k)}{10}\right)$$

It is necessary to take noise measurements for 24 hours in order to obtain the WNI from mesured values. The levels of effective perceived noise for each flyover are thus obtained. Those levels can be obtained either through exact procedures or approximate ones. Both are described in norm ISO.3891 according to their level of accuracy. The level of effective perceived noise, measured for the i flyover during the k time of the day, is know as L_{EPN} (i, k) and WNI calculation procedure is the following:

$$WNI = 10\log_{10}\left\{ \sum_{k=1}^{2} \sum_{i=1}^{n_k} p(k)\ .\ 10^{\frac{L_{EPN}\ (i, k)}{10}} \right\} - 68$$

To simplify matters, the WNI calculation procedure could be re-written like this:

$$WNI = 10\log \sum_{day} \text{ANTILOG}\left(\frac{L_{EPN}\ (1,1)}{10}\right) + 10 \sum_{night} \text{ANTILOG}\left(\frac{L_{EPN}\ (i,2)}{10}\right) - 68$$

2.4. RELATIONSHIP BETWEEN THE WEIGHTED NOISE INDEX AND SUBJECTIVE NUISANCE

The analysis of all the known nuisance noise level assessment methods shows the universal agreement that the weighted mean of noise levels generated by each flyover represents a value of people's nuisance. Several experiments have shown that increases in nuisance level actually represent increases in subjective nuisance felt by people. On the other hand, it is not only subjective nuisance that must be taken into account but also the way people react to noise.

In countries and regions inhabited by high-income populations noise pollution restrictions are greater. In Brazil, preliminary studies have been performed and compared with other countries results. The following table depicts the conclusions drawn thereafter.

2.5. METHODOLOGY TO GENERATE ISOPHONIC COUNTOURS

As depicted in Table 1 the contour encompassing all the points in the airport environs whose nuisance level were WNI 53 and the countour which encompassed all WNI 60 points would be extremely helpful to urban planners.

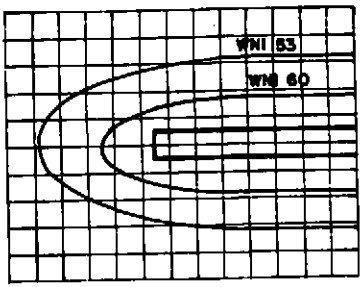
Based on these contours, it's possible to plan the land use in airport environs as well as attempt to minimize the problem of the existing communities by controlling landing and take-off routes in the airport. The method in generating isophonic contours is the following:

1. A grid is drawn for the airport environs, as shown in picture 1.

TABLE 1

Weighted Noise Index Value	Community Reaction when exposed to this level of nuisance
Below WNI 53	No complaints expected
Between WNI 53 and WNI 60	A considerable number of complaints is expected
Above WNI 60	A large number of complaints is expected. Residents may take legal action in order to reduce the level of nuisance.

PICTURE 1



2. WNI value is calculated for each point.
3. When considering two adjacent points, if the WNI value of one of them is greater than the desirable value and the WNI value of the other is less, an interpolation is done in order to determine the contour point.
4. The determination of various points in the isophonic contour allows for the calculation of the intermediate points and thus the plotting of the contour.

The assessment of the noise pollution magnitude derived from airport operations is initially based on the growth of the airport air traffic over a period of time up to twenty years. Those studies take into account air fleet evolution, the growing number of operations in the airport, diversification of the links and possible alterations in landing and take-off routes. The noise impact is determined for several horizons and the most critical one is selected based on those data and according to the procedures described above. In this case, WNI 53 and 60 noise contours are regarded as the Noise Zoning Plan for the airport under consideration.

Based on that plan, an urbanization proposal for the airport environs is elaborated, avoiding land uses incompatible with expected noise levels. Therefore, in the long run, there will be corridors in the airport adjacent areas through which aircraft will fly without damaging near-by communities.

The most important tool to reconcile urban and airport planning is therefore the so-called Noise Zoning Plan, introduced by the Federal Decree number 83.399 of May 3rd, 1979 and incorporated to Brazilian Air Code by Law 6.997 of June 7th, 1982.

The Noise Zoning Plan defines areas subjected to critical airport noise level exposure. It supplies the basis for an appropriate land use in airport environs, assuring a harmonious and complementary relationship with the community living there. Moreover, the Noise Zoning Plan is the most effective tool in protecting Brazilian Airports against urban encroachment, and in helping urban and airport authorities involved in this kind of problem.

Noise Zoning Plans have been carried out for more than 50 Brazilian Airports since their creation.