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Note

Analysis of airport noise through L_{Aeq} noise metrics

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ABSTRACT

The methodology used in several countries for airport noise simulations, including Brazil, is based on Day-Night Sound Pressure Level (DNL) metric. However, DNL metrics can in some cases bring distortions for sound levels, daily and nightly. The purpose of this study is to make an analysis of airport noise through the L_{Aeq} metric and propose new alternatives based on Day Equivalent Sound Level (L_{AeqD}) and Night Equivalent Sound Level (L_{AeqN}) noise metrics. We also apply the concept of acoustic influence areas for the analysis.

1. Introduction

An Airport induces development but also imposes several restrictions on the land use in the vicinities, which are not always respected. For example, in some cases the communities are allowed to live around the airport and they are commonly annoyed due to the high level of the aircraft noise emissions.

In order to mitigate the impacts related to aeronautical noise, the 33rd meeting of the International Civil Aviation Organization (ICAO), held in October 2001, adopted the A33/7 Resolution, which defines the concepts of Balanced Approach. The vast majority of countries in the world follow the guidelines of this resolution aiming a better management, control and mitigation of airport noise and its adverse effects. Noise reduction at the source, land use and planning, operational procedures for noise reduction, and operational restrictions are suggested alternatives.

L_{Aeq} is used for urban zoning in Brazil (ABNT NBR 10151, 2000); however airport zoning is done through DNL metric (RBAC, 2011). According to the Code of Federal Regulations 14 CFR 150 (2004), The United States also applies DNL metric for airport zoning and some European countries prefer Day–evening–night level – L_{DEN} (European Parliament Directive 2002/49/EC).

The development of studies related to the human response to aircraft noise is very important for characterization of the sound environmental impact. Initially, Schultz conducted research relating the percentage of highly annoyed people through DNL metric (Schultz, 1978). Federal Aviation Administration (FAA) uses DNL 65 criterion for compensating the communities around airports experiencing aircraft noise induced annoyance (FAA, 1985). Other studies were developed to predict human response to noise, relating the community's reaction to DNL values (Fidell et al., 1988; Fidell, 2003; Kryter, 1982; Miedema and Vos, 1998).

Although DNL is still being used as noise metric for airport zoning in many countries, some criticisms are related to the fact that the results using the DNL metric do not change very much with the inclusion of few nightly noisy events. Nightly airport noise may increase the probability of awakenings, which could be a cause of increased annoyance. Also during the loudest part of a noise event, it could interfere with communications even though the average level over several hours is low (More, 2011; Slama et al., 2008).

The tendency of increasing share of air transport in the global market tends to expand exponentially, keeping the expectation of its evolution. This fact suggests that the establishment of a buffer zone[1] around airport's sites, beyond DNL 65 dB, can prevent the intensification of the conflicts already existing between the airports and the cities, so that both can grow (Caldas et al., 2012).

In a previous study, the authors conclude for the suitability of guiding land use around airports, based on references that consider daytime and nighttime noise exposure, reflecting, in a more accurately way, the actual impacts resulting from operations in its zone of influence (Heleno and Slama, 2008).

The noise monitoring consists on determining the sound pressure levels and characterizing the environmental impact produced by the aircraft noise around the airport. Main international airports has implemented several measures to reduce noise

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[1] Noise Buffer Zone – Area subject to special guidelines for noise abatement, where, sensitive pre-existing activities, such as schools and hospitals, would be appropriate for acoustic treatment, and where other facilities sensitive to noise would be discouraged by the land use and occupation regulations.

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and have also installed noise monitoring systems that collect data on the actual noise levels values during aircraft landing and taking off, which is then analyzed and used to inform the community (Barbo et al., 2009; DLR, 2011; Girvin, 2009). L_{Aeq} metrics increase noise characterization during the night and day. We can say that its use can contribute to implement new mitigation measures.

2. Noise descriptors

2.1. Day–night sound level and Day–evening–night sound level – DNL

DNL is an equivalent continuous A-weighted sound pressure level with an addition of 10 dB(A) during the night-time (ANSI S3.23, 1980). L_{DEN} also adds 5 dB(A) during the evening-time. It reflects the fact that people are more sensitive to noise during the night. This is mainly because the background noise level is reduced at night which causes aircraft events to be more noticeable. Equations (1) and (2) define DNL and L_{DEN} metric.

$$\mathrm{DNL} = 10\log\left\{1/24\left[\int_{7}^{22}\left(10^{(LA(t)/10)}\right)\mathrm{d}t + \int_{22}^{7}\left(10^{((LA(t)+10)/10)}\right)\mathrm{d}t\right]\right\} \tag{1}$$

$$L_{DEN} = 10\log\left\{1/24\left[\int_{7}^{19}\left(10^{(LA(t)/10)}\right)\mathrm{d}t + \int_{19}^{22}\left(10^{((LA(t)+5)/10)}\right)\mathrm{d}t + \int_{22}^{7}\left(10^{((LA(t)+10)/10)}\right)\right]\mathrm{d}t\right\} \tag{2}$$

2.2. Equivalent sound pressure level – L_{Aeq}

L_{Aeq} is used to evaluate various types of noises. It indicates the average sound level resulting from the integration throughout a period of time that can be defined with the logarithmic sum of all sound levels (Bentes and Slama, 2011). Equation (3) defines L_{Aeq} metric.

$$L_{Aeq} = 10\log\left\{1/T\int_{t1}^{t2}\left(P_{A(t)}/P_0\right)^2\mathrm{d}t\right\} \tag{3}$$

Where T is the time period, $P_{A(t)}$ is the instantaneous sound pressure and P_0 is the reference pressure, 2×10^{-5} Pa. In the case of the aeronautical noise, due to the characteristics of non-stationary noise, we can use L_{AeqD} and L_{AeqN} metrics, representing the equivalent sound levels calculated in a critical receptor near an airport during the day and night periods. These metrics are defined by equations (4) and (5):

$$L_{AeqD} = 10\log\left\{1/15\int_{7}^{22}\left(10^{(LA(t)/10)}\right)\mathrm{d}t\right\} \tag{4}$$

$$L_{AeqN} = 10\log\left\{1/9\int_{22}^{7}\left(10^{(LA(t)/10)}\right)\mathrm{d}t\right\} \tag{5}$$

3. Methodology

Noise contour is a graphical representation of the sound pressure level from aircraft movements at the airport. The DNL metric is widely used to define the level of noise exposure caused by the operation of aircraft in a community. The airport zoning regulations in many countries, including Brazil, is based on the use of the DNL and residences are authorized by the airport in areas where DNL $\leq$ 65 dB(A).

According to the legislation, a noise impact would be significant in areas above 65 dB(A). However, the use of the DNL metric can be associated to different daytime and nighttime noise levels depending on the number of airport movements in these periods. For a better evaluation of sound impacts caused by aircraft noise urban noise was proposed to use the L_{Aeq} metric. Sound impact caused by aircraft noise can be related to day and night effects, and it would be interesting to adopt noise metrics for the night and day periods as L_{AeqD} and L_{AeqN}. Noise contours using these metrics can give a good representation of the airport's acoustic characteristics as a noise source.

DNL, L_{AeqD} and L_{AeqN} noise contours of the Pinto Martins International Airport (SBFZ) were obtained by the use of the FAA's software – Integrated Noise Model (INM) taking into account the operational data from the airport, routes, flight numbers, takeoff and landing procedures, and aircraft model. These noise contours are used to assess the noise impact caused by the airport operation.

L_{AeqD} and L_{AeqN} contours values are compatible with ABNT NBR 10151 (2000) Standard. In this standard there is a separation of the day and night level evaluation criterion. These noise contours consider the possibility to visualize more clearly the areas more susceptible to the aircraft noise, thus identifying the acoustic of the airport. In this perspective, we proposed a methodology for obtaining these areas based on L_{AeqD} and L_{AeqN} metrics.

Another proposed alternative was based on a logical relation from on L_{AeqD} and L_{AeqN} noise contours with noise criterion levels defined for different areas as recommended by ABNT NBR 10151 (2000). For example, in a residential area with $L_{AeqD} < 50$ dB(A) and $L_{AeqN} < 45$ dB(A) is possible to write a unique logical condition associating a unique area defined by $L_{AeqD} < 50$ dB(A) AND $L_{AeqN} < 45$ dB(A), and the complementary area is delimited by $L_{AeqD} \geq 50$ dB(A) OR $L_{AeqN} \geq 45$ dB(A), which represents an area of exclusion for activities sensitive to noise, for example, strictly residential areas, hospitals and/or schools. Therefore, the same procedure was adopted for other areas defined in Table 1, and a representative curve was obtained for each logical condition.

Table 1
Logic condition proposed airport zoning.

L_{AeqD} dB(A)	L_{AeqN} dB(A)	Description	Logic condition
50	45	Strictly urban residential, hospitals or schools	$L_{AeqD} < 50$ AND $L_{AeqN} < 45$
55	50	Mixed, predominantly residential	$L_{AeqD} < 55$ AND $L_{AeqN} < 50$
60	55	Mixed, commercial and administrative vocation	$L_{AeqD} < 60$ AND $L_{AeqN} < 55$
65	55	Mixed, recreational vocation	$L_{AeqD} < 65$ AND $L_{AeqN} < 55$
70	60	Mainly industrial	$L_{AeqD} < 70$ AND $L_{AeqN} < 60$

Source: Study Group in Airport Noise (GERA), 2013.