NOISE LIMITS FOR LAND-USE COMPATIBILITY: A COST-EFFECTIVENESS ANALYSIS FOR BRAZILIAN AIRPORTS

Bruno Arantes Caldeira da Silva
Instituto Tecnológico de Aeronáutica
brunoacs@gmail.com

Rogéria de Arantes Gomes Eller
Instituto Tecnológico de Aeronáutica
rogeria@ita.br

ABSTRACT

This paper intends to estimate the cost related to making residences impacted by aircraft noise around Brazilian airports compatible to the noise standards. For that, noise modeling of 29 Brazilian airports was performed, and data from the latest population census was used (2010). It was considered the installation of acoustic windows as the mitigation measure to be used. The results show that the noise level criteria used to define the need for acoustic insulation has a great influence on the costs involved, which points to the need of different approaches to address aircraft noise issues instead of simply reducing the noise criteria for compatibility.

Keywords: airport noise, cost effectiveness analysis, noise compatibility criteria, noise limits, land-use planning.

1. INTRODUCTION

Aircraft noise is one of the main environmental problems currently hindering the development of civil aviation over the world. Several measures are currently being taken in order to mitigate its impact, such as: noise-related taxes, limits, quotas and budgets, definition of noise preferential routes and runways, low noise operational procedures, curfews, phase-out of noisier aircraft and land-use planning and management (Girvin, 2009).

Specifically on land-use planning in Brazil, ANAC RBAC 161 – "*Planos de Zoneamento de Ruído em Aeródromos*" currently considers noise levels over 65 L_{DN} (day-night average sound level) as incompatible for residential land uses. However, this value is not aligned with the lower noise levels for comfort defined in National Standard ABNT NBR 10.151. This conflict between regulations is currently leading to several conflicts between the airports and its neighbors, since the higher acceptable levels defined in RBAC 161 are often questioned by the affected communities (Brasil, 2010).

This work intends to estimate the cost involved with the sound insulation of the residences affected by aircraft noise in Brazil, in order to evaluate both standards from the point of view of this metric.

2. HISTORICAL BACKGROUND

The consideration of aircraft noise in land use planning around Brazilian airports mainly started in 1982 with Federal Law 6997, which modified the Brazilian Air Code to require a Noise Zoning Plan to define land use restrictions around Brazilian airports. This zoning was further defined by Decree 89.431, in 1984, which defined the IPR (*Índice Ponderado de Ruído* – Weighted Noise Index) as the noise metric to be used for the noise zoning around airports (Brasil, 1984).

The technical details involved with the metric calculation were defined in IAC 4102, in 1981. In brief, the IPR was based on the WECPNL (Weighted Equivalent Continuous Perceived Noise Level), metric defined proposed by ICAO (International Civil Aviation Organization) to measure the noise impact of aircraft operations over its surroundings.

IAC 4102 also defined IPR levels for land-use compatibility: noise levels under IPR 53 were deemed compatible for all purposes, since no noise complaints were expected on those situations.

Later on, in 1987, ABNT (Brazilian Technical Standards Organization) issued the standard NBR 10.151, which used the L_{AeqD} and L_{AeqN} (equivalent continuous A-weighted sound pressure level for day and night, respectively) as the noise metrics for noise evaluation at communities, thus also presenting different noise limits for day and night. This standard was later referenced by Resolution 001/1990 of CONAMA (*Conselho Nacional do Meio Ambiente* – National Environmental Council) to be used for noise evaluation of industrial, commercial, social and recreational activities.

Finally, ANAC (*Agência Nacional de Aviação Civil* - Brazilian Civil Aviation Agency) issued, in 2011, the RBAC 161, which is the regulation in force for airport noise evaluation. This requirement is aligned with its American counterpart (14 CFR Part 150) in terms of noise metric and limits for compatibility, since it also uses the L_{DN} as noise evaluation metric and considers all land uses compatible with noise levels under 65 L_{DN}.

Revoredo and Slama (2007) presented a detailed comparison of the applicability of these noise level limits in Brazil, pointing out to the need to harmonize these standards. With the equations developed on that work, it can be seen that a simple conversion of the NBR 10.151 limits to the L_{DN} metric would yield significantly lower limits than the 65 L_{DN} defined in RBAC 161. This conversion is depicted in Table 1:

Table 1: NBR 10.151 criteria conversion to L_{DN}

Land use type	L_{AeqD}	L_{AeqN}	L_{DN}
Strictly urban residential, school or hospital areas	50	45	52.6
Predominantly residential mixed areas	55	50	57.6

The relationship between L_{AeqD}, L_{AeqN} and L_{DN} is defined in (1), as demonstrated in Revoredo and Slama (2007).

$$L_{DN} = 10log_{10}\left[\frac{1}{24}\left(15 \times 10^{\frac{L_{AeqD}}{10}} + 90 \times 10^{\frac{L_{AeqN}}{10}}\right)\right] \quad (1)$$

3. NOISE AND ANNOYANCE MODELING

Noise modeling was performed for the 29 airports which presented the highest number of airplane movements in the year 2010. This modeling was performed with INM (Integrated Noise Model), software developed by the FAA (Federal Aviation Administration) that models the noise generated by a specific combination of aircraft movements (FAA, 2008). In the present work, this information was obtained from ANAC databases. The modeling considered straight takeoff and landing paths, in the direction of the airport runways. The list of modeled airports is depicted in Table 2:

Table 2: Airports considered in the noise modeling

	CIDADE / NOME
SBGR	GUARULHOS
SBSP	SÃO PAULO
SBBR	BRASÍLIA
SBGL	RIO DE JANEIRO - GALEÃO
SBRJ	RIO DE JANEIRO - SANTOS DUMONT
SBSV	SALVADOR
SBPA	PORTO ALEGRE
SBCF	BELO HORIZONTE - CONFINS
SBCT	CURITIBA
SBKP	VIRACOPOS
SBRF	RECIFE
SBGO	GOIÂNIA
SBFZ	FORTALEZA
SBBH	BELO HORIZONTE - PAMPULHA
SBCY	CUIABÁ
SBEG	MANAUS
SBBE	BELÉM
SBFL	FLORIANÓPOLIS
SBVT	VITÓRIA
SBRP	RIBEIRÃO PRETO
SBLO	LONDRINA
SBBI	CURITIBA
SBUL	UBERLÂNDIA
SBCG	CAMPO GRANDE
SBNT	NATAL
SBPR	BELO HORIZONTE - CARLOS PRATES
SDCO	SOROCABA
SBSL	SÃO LUÍS
SBSJ	SÃO JOSÉ DOS CAMPOS

For the evaluation of number of people subject to noise levels, it was used the Census data from the year 2010, given by IBGE (*Instituto Brasileiro de Geografia e Estatística* – Brazilian Institute of Geography and Statistics). The limits of the Census sectors were used to calculate its centroid points, in order to allow its population to be input in the INM software. This concept is illustrated in Figure 1:

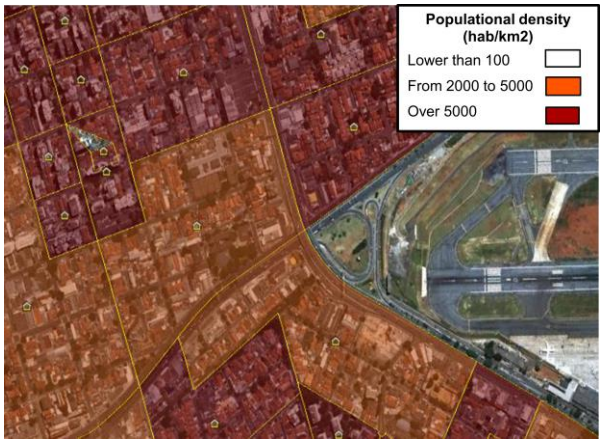


Figure 1 - Census sectors and its centroids, close to SBSP runway

The L_{DN} was used as noise metric, as defined by RBAC 161. The total number of people subject to noise levels between 55 to 75 L_{DN} was calculated from the modeling. The results are summarized in Figure 2, which considers all the airports simulated:

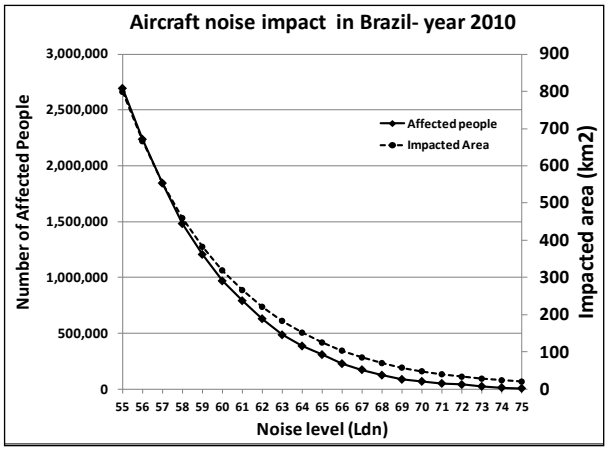


Figure 2: Modeled impact of aircraft noise in Brazil, in terms of affected people and area

The results show that, considering the current noise level adopted by RBAC 161 for residential compatibility (65 L_{DN}), there were about 300.000 people living in areas with unacceptable aircraft noise levels. The graph also shows that, for noise levels lower than 65 L_{DN}, the number of people and affected area start to increase at a higher rate, reaching a number of 2.7 million people subject to noise levels of 55 L_{DN}.

The main environmental impact associated with aircraft noise is the annoyance it produces over people hearing the aircraft noise. In order to further evaluate this variable, Schultz (1978) defined as a descriptor of the noise environmental impact the percentage of people that is highly annoyed by an specific noise level. The curve derived by Schultz after analyzing data from several surveys relates the number of highly annoyed people with the noise levels in L_{DN}. It was used as basis for many land use regulations over the world, including the United States.

Figure 3 depicts the relation between highly annoyed people and L_{DN} defined in FICAN (1992) after a reassessment of Schultz work.

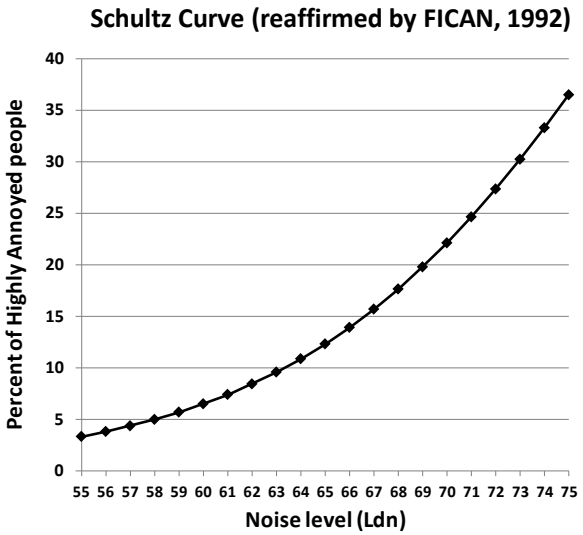


Figure 3: The Schultz Curve (FICAN, 1992)

4. COST-EFFECTIVENESS ANALYSIS

In the United States, the 65 L_{DN} noise level is used as criteria for the need of actions to address aircraft noise land-use issues (USA, 1984). ANAC RBAC 161 also requires that measures shall be taken to eliminate or reduce land uses non compatible with this criteria.

Several instruments may be used to achieve this noise compatibility, such as the acquisition of land and avigation easements, construction of acoustical barriers and change in flight path patterns.

However, in many cases, the only possible way to make a residence compatible is by the installation of acoustical insulation. This is the case in many Brazilian airports, since the proximity of the residences to the airport generally makes it difficult to improve the noise levels by means of operational measures, and also the high cost of land near the airports makes unfeasible the simple acquisition of these areas and its incorporation to the airport area.

In order to estimate the cost related to the acoustic insulation of residences affected by aircraft noise in Brazil, it was adopted an insulation cost of $5,000 per person exposed, which is approximately the cost of installation of an acoustic window, as obtained from informal consultation to acoustic window suppliers in Brazil. This premise is in line

with other cost-effectiveness studies, such as the Swiss airports evaluation shown in European Commission, 2004.

The Schultz curve shows that, as expected, the number of highly annoyed people decreases as the noise level gets lower. This effect is particularly important in the discussion of mitigation measures for residences affected by noise: despite the fact that people are not equally annoyed by a certain noise level, the eligibility for an eventual insulation needs to be defined according to the noise level, since it is the physical variable that best correlates with the observed annoyance.

As the percentage of annoyed people reduce when the noise level gets lower, the number of "not annoyed" people which may be eligible to insulation increases as the noise criteria for insulation decreases. This effect reduces the cost-effectiveness of the proposed mitigation measure, since the expected result from the mitigation would be focused on the highly-annoyed people. In order to evaluate this, the Schultz curve was used together with the results shown in Figure 2, in order to calculate the cost related to the removal of one highly-annoyed person from the non compatible noise levels, as a function of the noise criteria used. The calculation process involved can be defined in three steps:

a) First, the number of people subject to a specific noise level (Figure 2) was multiplied by R$5,000, in order to estimate the total compatibility cost related to that noise level.
b) Then, the number of highly-annoyed people at each noise level was obtained by multiplying the data from Figure 2 with the Schultz Curve information (Figure 3).
c) Finally, the compatibility cost of one highly-annoyed person can be obtained dividing the total compatibility cost by the number of highly annoyed people at a certain noise level.

The result of this calculation is shown in Figure 4.

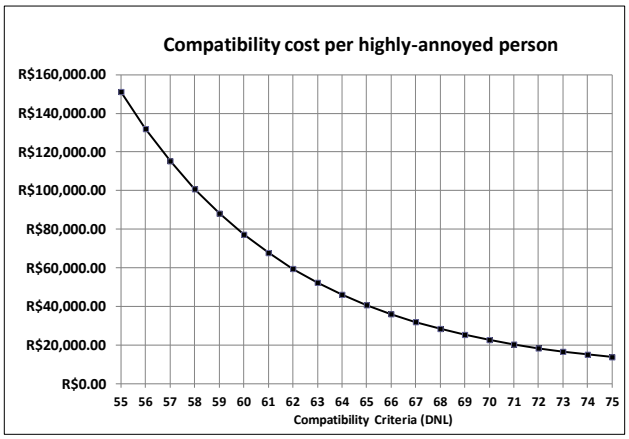


Figure 4 - Compatibility cost per highly annoyed person

The results show that the cost effectiveness of the acoustic insulation gets lower if the noise level criterion is reduced. For example, with the use of RBAC 161 criteria (65 L_{DN}), the compatibility cost of one highly annoyed person is in the range of R$40,000, and when the NBR 10.151 criteria for residential mixed zoning is used (57.6 L_{DN}), this cost rises to R$105,000.

5. CONCLUSIONS

This paper made a cost estimation of acoustic insulation of Brazilian residences affected by aircraft noise. The results show that the cost-effectiveness of this mitigation measure gets decreased with the use of lower noise compatibility criteria, due to the reduction on the number of highly annoyed people effectively reached by the measure.

The results point out that the involved costs may be rather high, especially for a developing country like Brazil. Given that scenario, airport noise issues should be addressed not only by setting lower noise compatibility criteria for land use, but also by foreseeing more precisely the annoyance produced by aircraft noise, which may help to inform the general public and the authorities about the aircraft noise in a region and, in medium to long terms, divert highly-annoyed people from locations where they may be affected by aircraft noise.

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