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Aircraft noise mapping: Bacacheri Airport

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ABSTRACT

Noise is nothing more than air pollution caused by increased vibration in the air. Environmental noise is the noise in the environment generated by several simultaneous sources, with the exception of occupational noise, with emphasis on roadway noise, construction noise, railway noise and aircraft noise. Aircraft noise is the noise generated mainly by aircraft operation at airports. Aircraft noise exposure causes considerable damage to life quality, health and well-being of the population near airports. As with all forms of pollution, noise must also be managed through the application of methodologies for identifying sources and receivers, highlighting, among the existing ones, the measurement of environmental noise and acoustic mapping of the area. The objective of this work was to verify the existence of aircraft noise in the area directly affected by Bacacheri Airport, in Curitiba, through the measurement of acoustic parameters and acoustic mapping. For this purpose, the Bruel & Kjaer 2238 sound analyzer and the Soundplan 8.0 software were used to measure aircraft noise and acoustic mapping, respectively. The results indicate that there is intense to moderate aircraft noise in the area surrounding the airport, as well as quantify the population exposed by the noise pollution generated at the airport being affected by the negative impacts. It is concluded that there is need for the airport to provide noise mitigation measures recommended by the International Civil Aviation Organization (ICAO).

PALAVRAS-CHAVE: Aircraft noise. Acoustic mapping. Noise management.

1 INTRODUCTION

Currently, air transport is one of the trivial structural axes for the economic development of cities, states and even at national level (ALONSO et al., 2017). Airport operation presents advantages and disadvantages: as it stimulates the economic development of the region in which it operates, it generates negative environmental impacts on the surrounding community. Among these impacts, the increase in air pollution by gas emission and noise pollution stand out. An aircraft's noise emission level during the initial take-off phase is influenced by several parameters (GAGLIARDI et al., 2018), such as its type and power, maximum speed, runway material, distance between source and receptors, climate conditions, takeoff time, etc. Aeronautical noise is a serious environmental problem which has been studied intensively over the years (FLORES et al., 2017). The impacts of prolonged exposure to aircraft noise can cause sleep disturbances, cardiovascular diseases, damage to the auditory system, stress, reduced professional or educational performance and behavioral changes (SANTÉ, 2016).

Like any other source of pollution, noise must be controlled and mitigated by the use of noise management instruments. In order to do so, firstly, the pollution generated must be identified and quantified, as well as the recipients exposed to it must be identified and estimated. Pollution identification and quantification can be performed through parameters measurement and acoustic mapping of the site.

Noise maps are the representation of an environment of interest whose function is to quantitatively and qualitatively identify the population exposed to a given noise indicator through outlines and colored areas for each of its levels at pre-defined intervals (EPA, 2011; OZKURT 2015). Acoustic maps are created from computational modeling which calculates the propagation of sound in open environments generated by specific sources. Each model has its own particularity, but generally speaking the basic input data are: topography of the site, buildings, vegetation, water bodies, climate conditions, sound absorbing elements and other relevant details dependent on the sound source of interest (EPA, 2011). Acoustic mapping, or strategic noise mapping, is essential in the diagnosis of areas affected by noise-generating activities as it allows the identification of critical locations, points and receivers and exposed areas as well as the assigned value, assisting in the decision making regarding noise management (ZANNIN, 2019), and its use has been growing in several parts of the world (NASCIMENTO et al., 2021).

In view of the above, the present study aimed to verify the existence of environmental noise in the area directly affected by the activity of Bacacheri Airport, in Curitiba, through measurement of parameters and acoustic mapping.

2 METHODOLOGY

Methodology was divided into three stages: data gathering and planning, acoustic parameter measurement and acoustic mapping.

2.1 STUDIED AREA

Bacacheri Airport (SBBI) is a small to medium-sized airport located in the neighborhood of Bacacheri, Curitiba/PR. It consists of a single runway, with aviation activity for executive air taxi flights, cargo transportation and aero school and has an annual passenger flow of approximately 300,000.

Bacacheri is predominantly a residential neighborhood, with economic activities focused on commerce and services, in addition to the presence of a military village. According to Municipal Law No. 9,800/2000, Bacacheri Airport's zone is ZE-M and the surrounding region presents ZR-1, ZR-3 and ZR-4 zoning. The region's zoning is important because of Curitiba's Municipal Law No. 16,625/2002, which establishes the noise limits in a place according to its zone and to the period of the day. This same law determines that, within a 200 m radius of schools and health centers, ZR-1 is considered. The noise limits according to each zone can be seen in Table 1.

Table 1: Noise limits by zoning in daytime

Zone	Daytime limit (dB(A))
ZR-1, ZR-2, ZR-3	55
ZE-M	60
ZT-LV, SE-LV, ZR-4, SE	65

Source: Adapted from Law No. 16,625, 2002.

2.2 AIR TRAFFIC

Model quantification and identification for the airport's operating aircraft were obtained referring to the year of 2018 through the Integrated Air Traffic Control and Air Defense Center II (CINDACTA II) annual report. The airport's annual air traffic indicates 7,140 operations with airflow distributed mainly between 8 am and 6 pm, with peak hours in the interval between 10 am and 11 am, followed by 1 pm and 3 pm, distributed in a similar way between the days of the week, consisting of 80% single-engine aircraft flow, 18% twin-engine aircraft flow and 2% jet aircraft flow, with AB11 and C152, single-engine aircraft models, representing more than

55% of the models that operated during the year. Aircraft quantification and models are essential, as they are used as input for acoustic mapping.

2.3 PARAMETERS MEASUREMENT

For the definition of the measurement points, the distance from the operating runway was considered, since, as Bacacheri Airport is small to medium-sized, with less powerful single-engine aircraft, the influence of other sound sources in the environment that may overestimate the measurement should be considered, because, the farther from the source of the aircraft noise the measurement is, the greater the probability of the measured value being subject to other sources of noise pollution (SARI et al., 2014). In light of these observations, five parameters measurement points were defined, all close to the runway in order to reduce the effects of other noise present in the environment. For acoustic parameters measurement, the Bruel & Kjaer Sound Analyzer model 2238, previously calibrated by the Bruel & Kjaer model 4231 calibrator, was used. The locations of the measurement points can be seen in Figure 1:

Figure 1: LAeq measurement points near the Bacacheri airport runway

Source: adapted from Open Street Map.

The measured parameter was the A-weighted, Equivalent Continuous Sound Level (LAeq) during daytime, with a duration of 1 hour and the measurements were made following the recommendations of NBR 13,368 / 1995 and NBR 10,151 / 2019, which are: protection from the effect of the wind in the microphone, meter height 1.20 m from the ground, minimum distance of 3 m from any reflective and sound-absorbing surfaces, good weather conditions, simultaneous measurement of background noise, relate the type of aircraft and measure on flat surfaces. Some of the *in situ* measurements can be seen in Figure 2.

Figure 2: LAeq measurement, points 1 and 3

Source: The authors, 2019.

2.4 ACOUSTIC MAPPING

2.4.1 DEFINITION OF THE CALCULATION MODEL

Acoustic mapping consists in two stages: pre-processing and post-processing. The pre-processing step consists in preparing the model before performing computational calculations. Therefore, the physical scenario of the region of interest must be created through the insertion of the altimetric points and the creation of the digital terrain model, digitalizing all the environmental elements of the area, such as highways, vegetation, buildings, creation of the airport element and insertion of air traffic. Then, the calculation method and the calculation grid are defined so the computational calculations are finally performed. For the acoustic mapping process of Bacacheri Airport, the SoundPlan 8.0 software, Aircraftnoise module was used, and the calculation model defined for acoustic mapping was the model ECAC.CEAC doc. 29/1997 of the European Civil Aviation Confederation (ECAC), a model widely used in making noise maps in Europe (HAMANCI et al., 2017; OZKURT, 2014; SARI et al., 2014). A 2x2 meters calculation grid was adopted.

2.4.2 MODEL VALIDATION

Fundamental step of the methodology, the mathematical model validation indicates how close its simulated mapping is to the real situation; therefore, the noise map must always be validated after its confection. The model validation has the function of attesting the veracity of the simulation by comparing the simulated values in the model with parameters measured *in situ*. The Portuguese Environmental Agency (APA) (2011) suggests that the maximum difference between the simulated value and the measured value is up to ± 2 dB(A).

3. RESULTS

The *in situ* results at the measurement points can be seen in Table 2, being compared to the values simulated by acoustic mapping. Of the five measured points, only point 4 is outside the APA (2011) recommendations. Sari et al. (2014) found differences of up to 7 dB(A), Gerolymatou et al. (2019) found differences of 2.5 to 23% and Licitra et al. (2014) obtained variations of 3 to 6 dB(A) and, after calibrating the model, a maximum variation of 1.7 dB(A). In the used model, absolute variations between 0.6 to 2.5 dB(A) were found, as well as a relative error of 4.16%, thus the model is considered to be valid.

Table 2: Comparison between measured and simulated values

Point	Measured value (dB(A))	Simulated value (dB(A))	Difference between measured and simulated (dB(A))	Relative error (%)
1	67.1	66.2	0.7	1.19
2	57.0	58.8	-1.8	3.15
3	71.0	69.3	1.7	2.39
4	60.0	62.5	-2.5	4.16
5	63.6	64.2	-0.6	0.90

Source: The authors, 2019.

Through acoustic mapping, it was possible to identify the receivers as well as to estimate the inhabitants exposed to noise pollution by noise bands, according to Table 3. As the lowest maximum value allowed for the airport surrounding area zoning was 55 dB(A), in zones of silence (ZR-1), the mapping process was done through the identification of the areas affected by this equal-loudness aircraft noise contour, in addition to the indication, through circles, of the presence of critical points to noise, such as schools and health centers. The acoustic mapping results can be seen in Figure 3.

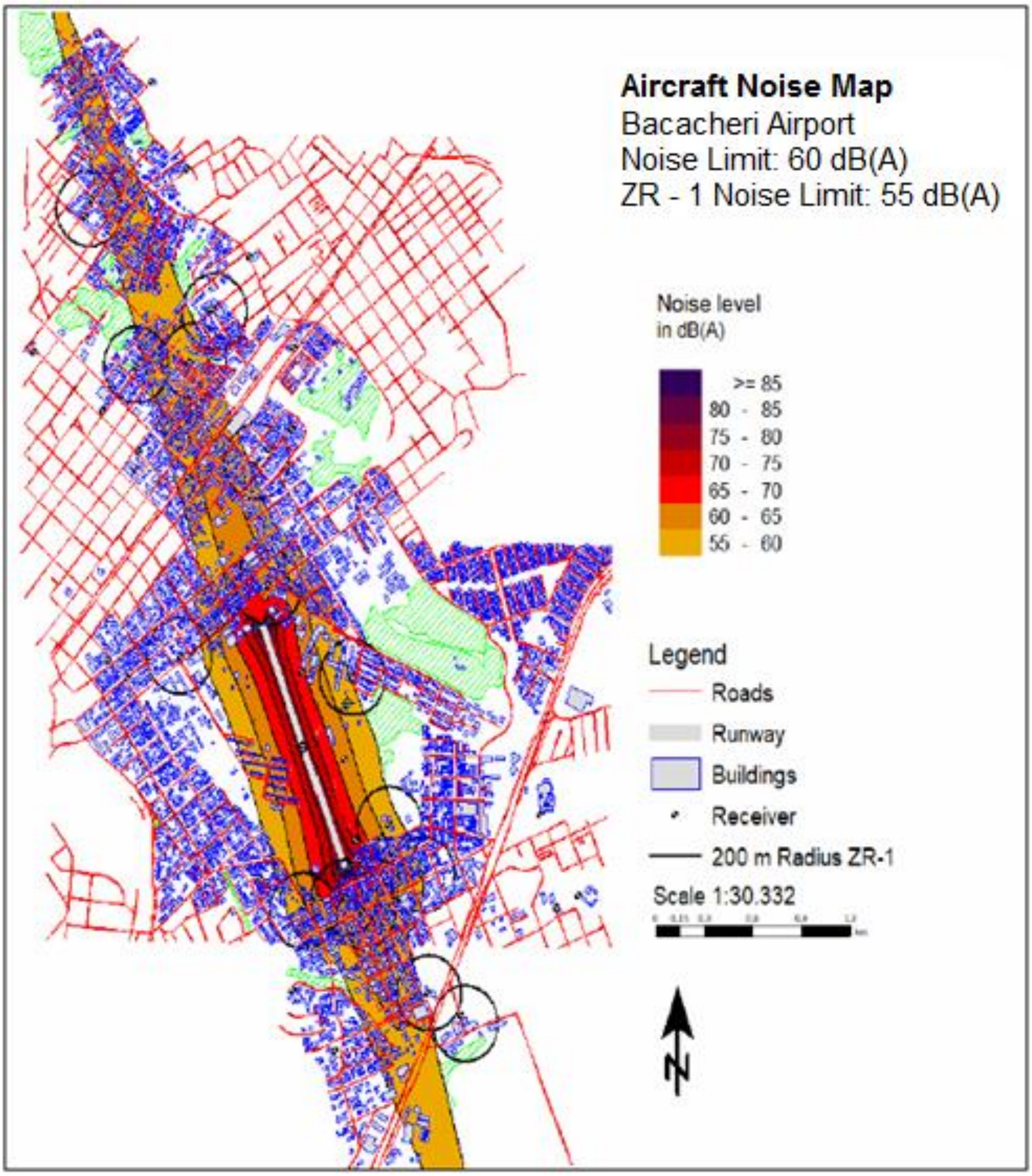
Table 3: Quantification of receivers affected by noise pollution at Bacacheri Airport above 55 dB(A).

LAeq (dB(A))	Schools	Health centers	Area (m²)	Buildings	Population (inhabitants)
85-80	-	-	13,825	-	-
80-75	-	-	108,390	8	20
75-70	-	-	302,733	36	60
70-65	-	-	613,054	229	1,600
65-60	3	1	1,346,753	1,150	4,500
60-55	4	-	4,462,360	4,410	15,250

Source: The authors, 2019.

It is possible to note, through the LAeq measurements and the acoustic map, the occurrence of noise pollution from the activities of Bacacheri Airport, which negatively impacts the population of its surroundings, degrading life quality and social well-being, in addition to affecting school activities in the region. It is important to stress that the inhabitants identified in the pollution ranges above 70 dB(A) are very close to the runway thresholds, from where the aircraft takes off.

Figure 3: Bacacheri Airport acoustic map.



Source: The authors, 2020.

According to ICAO (2007), in order to reduce or eliminate aircraft noise, the airport must provide a program of noise reduction targets, called Balanced Approach. The program consists in identifying the sources and stages which generate noise at the airport through monitoring and application of four instruments that interact with each other, these being:

1) reduction of noise at source: consists in noise reduction in the propulsion system or in the aerodynamic structure of the aircraft. Aircraft are provided with noise emission certificates, and, as a result, the airport can propose internal policies allowing only aircraft with updated noise certificates;

2) land-use planning and management: the area surrounding the airport should preferably not be inhabited, let alone densely populated due to negative impacts. Therefore, in order for this to happen, there must be a prior articulation with local authorities in order to provide a socially and environmentally suitable urban zoning. For the specific case of Bacacheri Airport, since there already is urban consolidation around it, there is no possibility of relocating residents; however, there is the possibility of an articulation between the airport and Curitiba City Hall in order to discuss and propose changes in noise regulations in the city.

This articulation involves the adaptation of the site considering the existence of the airport, consolidated for years in the municipality, showing to current and future inhabitants the existence of a noise polluter undertaking, whereas the site's zoning is compatible with its land use and occupation;

3) noise abatement operational procedures: consists in a set of operational procedures at the airport to reduce noise generated on the runway, such as creating thresholds farther from inhabited areas, towing planes to the garage, prioritizing steeper takeoffs over long distances traveled on the ground, among others;

4) operating restrictions: it is based on the implementation of operating restrictions at the airport, such as restricting aircraft authorization with outdated noise certificates or the circulation of specific aircraft within pre-defined time bands and maximum number of daily operations.

4. CONCLUSIONS

The mapping results indicate that the area and population surrounding Bacacheri Airport are subject to adverse health effects, such as sleep disturbances, irritation signs, ringing in the ears, headaches, discouragement and partial or total hearing loss due to exposure to noise above 55 dB(A), to which the longer they are exposed, the greater the health damage is. It is noteworthy the presence of schools and health centers exposed to noise pollution above permitted, places considered sensitive to noise due to their social functionality. In view of these results, considering its socioeconomic importance, it is concluded that the airport should focus on prevention through the creation of noise reduction measures in order to mitigate the generated pollution, based on the guidelines and instruments recommended by the ICAO. In addition, the results indicate that the acoustic mapping process is of great use for noise pollution management and urban development and planning.

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