XXVII Congresso Nacional de Estudantes de Engenharia Mecânica
08 a 12 de fevereiro de 2021, Curitiba, PR, Brasil

Annoyance caused by aircraft noise in the proximities of Bacacheri Airport

Giovanni Corsetti Silva, corsetti@ufpr.br[1]
Daniel de Oliveira e Souza, daniccr@gmail.com[1]
Paulo Henrique Trombetta Zannin, paulo.zannin@gmail.com[1]

[1] Universidade Federal do Paraná, Av. Coronel F. H. dos Santos, 100 – Jardim das Americas, Curitiba, PR, Brasil

Abstract. *This paper describes the reactions to aircraft noise of people living in the vicinities of a medium sized airport, in this case the airport of Bacacheri, located in a densely populated urban area, based on questionnaires handed out to 250 people living or working near the airport in order to determine the effects of aircraft noise and environmental noise in their lives. Sound maps were also created to evaluate the impact of noise generated by the airport. It was stated that the maximum equivalent sound pressure level (L_{Max}) generated during takeoffs exceeds 100 dB(A). It is reasonable to consider that one-third of people living near Bacacheri Airport feel particularly annoyed between 6 and 8 a.m. due to the highest flow of airplane takeoffs and landings.*

Keywords*: Aircraft Noise. Environmental Noise. Noise Annoyance. Noise Mapping.*

1. INTRODUCTION

Noise pollution does not occur exclusively in industrial environments anymore, but also in small, medium and large cities all over the world. Prolonged exposure to intense sounds results in negative effects on human health, such as hearing impairment, cardiovascular disorders, mental problems and others (Hygge, 2001). Noise pollution is a problem affecting both developed and developing countries, such as China and Brazil (Zannin and Bunn, 2014).

Noise pollution from aircraft is an issue of paramount importance for the aerospace industry and is especially annoying for the population in the surroundings of airports (Blais, *et al*., 2013; Merino-Martinez, *et al*., 2016). Driven by the global GDP growth, air traffic is projected to grow in the long term, which will also lead to an increased aviation noise exposure for people near airport infrastructures (Gerolymatou, *et al*., 2019). The noise produced by airplanes depends on several factors, such as the type of aircraft, its flying height and speed, the amount of daytime and nighttime takeoffs and landings, flight configuration and others, making the enforcement of environmental laws a burdensome task due to this large noise level variability (Merino-Martinez, *et al*., 2016; Tsai, *et al*., 2009).

Licitra *et al.* (2014) describe some noise mitigation measures for airports, such as minimizing thrust reverse performances, acoustic barriers next to the apron, advance of takeoffs. Increasing air traffic and urban growth aggravate noise-related problems, while the reduction of aircraft noise and implementation of restrictions on air traffic and flight paths contribute to reduce the resulting annoyance.

The present work focuses on the reactions to aircraft noise of people living in the surroundings of Bacacheri Airport, which is located in the city of Curitiba, Brazil. This airport basically operates national flights, and Brazil's second integrated center for air defense and air traffic control is also located at this airport.

2. MATERIALS AND METHODS

2.1. Application of the questionnaire

The study sample was selected among men and women between 15 and 83 years old that have lived or worked in the Bacacheri neighborhood for less than one year or for more than five years, considering the year of 2016 as the reference. The interviewed people were randomly selected to avoid selection bias. A total of 250 questionnaires was handed out at homes and business establishments to obtain responses from the population located in the vicinity of Bacacheri Airport. The respondents were asked to fill out the questionnaire within two weeks, after which it would be collected.

In this research, the independent variables are the respondents' age and sex. The dependent variables are the respondents' answers. The results obtained from the questionnaires were quantified according to a simple and relative (percentage) distribution.

2.2. Acoustic mapping

As stated by Kurra (2020), Noise maps are graphical representations of noise level distribution in the environment, over a layout plan or regional plan incorporated into a geographic map. Since the radiation of sound from a source is a space-related phenomenon, it is reasonable to represent noise levels in two- or three-dimensional spaces. Noise maps are using sophisticated acoustic mapping software programs, that can calculate noise emission levels for a large number of points at the site under study. This resource enables one to determine the noise level at any point with a delimited area from a direct reading of the map with high degree of confidence, since measurements performed by software is very close to real-world results (Gerolymatou, *et al.*, 2019). Several countries are already successfully controlling noise based on acoustic maps (Ko, *et al*., 2011; Murphy and King, 2010).

Acoustic maps are excellent tools for the management of environmental noise and can be used to quantify main sources of noise, clearly illustrate environmental noise exposure to: 1) provide a reference for policy makers; 2) facilitate the development of policies for controlling noise and enforcing the control of noise; 3) draft a cost-benefit plan to assist districts desiring to reduce noise levels; 4) adopt theory to examine the effect of environmental improvement plans; 5) improve the enforcement of regional or national plans to decrease new noise resource as well as to protect new noise sensitive and tranquility needed areas; 6) monitor noise reduction schemes and their effectiveness during the enforcement process; 7) monitor changing trends in environmental noise; 8) provide a research platform for studying effects of noise on the human body (GBDE, 2001; Tsai, *et al*., 2009).

An important information regarding software programs that estimate noise maps is that they allow parameters manipulation that determine both noise emission and immission. They are, therefore, a valuable working tool to assess the impacts of noise in urban and industrial environments.

Recently aircraft noise models have been greatly improved, as aircraft noise maps are now mandatory in many some countries (Olsen, 1995). Accordingly, noise maps were created from the noise emitted by aircrafts to the surrounding region of Bacacheri Airport using SoundPlan version 6.2 software in order to analyse the noise emitted to the vicinities of the airport.

3. RESULTS AND DISCUSSION

Questionnaires were handed to 250 residents and workers in the Bacacheri neighborhood, 205 (82%) of which were filled out and returned to the researchers. Forty-one of the questionnaires (16%) were returned unanswered, and four (2%) were mislaid by respondents. The respondents of this study comprised 205 adults: 107 men, 94 women, and four people who did not identify themselves. Table 1 shows the distribution of the respondents of the questionnaire by number and age group.

Table 1. Physical characteristics of the sample (Author, 2016)

Respondents (sex)	Nº of respondents	Age group (years old)
Men	107	21 – 78
Women	94	15 – 83
Not identified	4	-
Total	205	-

Table 2 displays the age groups and number of male and female respondents in each group. As can be observed, for males the largest proportion of respondents were 38 to 40 years old, representing 40% of the total number of male respondents, meanwhile for females the largest proportion were 21 to 25 years old, representing 21% of the total number of female respondents.

Table 2. Age groups and number of male and female respondents in each group (Author, 2016)

Age groups (years)	Nº of male respondents	Age groups (years)	Nº of female respondents
21 – 25	5	15 – 20	13
26 – 30	5	21 – 25	21
31 – 35	15	26 – 30	15
38 – 40	44	31 – 35	6
41 – 45	15	37 – 41	8
46 – 50	5	42 – 47	11
51 – 55	6	48 – 51	9
56 – 60	4	56 – 60	3
62 – 67	4	64 – 65	5
70+	4	70+	3

Regarding the level of education of the respondents, 25% had a university degree, 19% finished primary school, 11% did not answer and the bast majority of responders, 45%, had a complete secondary education. With respect to the respondents' activities, 48% worked in the Bacacheri neighborhood but did not live there, 28% both lived and worked there, and 24% lived in the neighborhood but did not work there. A large majority of the respondents, 49%, had lived in the neighborhood for more than five years, 32% had lived there for 1 to 5 years, and 19% had lived there for less than one year.

When asked if they believed that noise can be harmful to health, the vast majority of respondents, 86%, answered "yes," while 61% of the respondents stated that aircraft and environmental noises have increased since they moved into the Bacacheri neighborhood. For both cases, the confidence interval for α=5% can be found from the conservative bond equation, illustrated in Eq. (1):

$$L_{cons} = \left[\overline{R}_n - \frac{1.96}{2\sqrt{n}}, \overline{R}_n + \frac{1.96}{2\sqrt{n}}\right] \quad (1)$$

where $\overline{R}_n$ represents the sample average and n the sample size. Replacing the obtained values for the studied sample, the number of people in the vicinities of Bacacheri airport that believe in the harmfulness of noise to health is around [79%,93%], meanwhile [54%,68%] believe that the aircraft noise has increased, both cases for a confidence interval of 95%. Thus, it is reasonable to state that more than half of people around Bacacheri airport feel that aircraft noise increased.

Table 3 shows the period of the week and the annoyance perceived by the local population. Weekdays are clearly the most annoying for the population, mainly due to the aircraft noise and road traffic noise.

Table 3. Period of the week with the highest level of annoyance (Author, 2016)

Period of the week	Annoyed individuals (%)
Weekdays – Monday to Friday	83
Weekends	8
Weekdays + Weekends	7
Did not answer	2

The city of Curitiba is located in a sub-tropical region of southern Brazil, and is considered the coldest capital of Brazil. However, there are periods during the summer when the weather is very hot. In response to the question of whether they sleep with the windows open in summer, 71% of the respondents stated that they did not, and 49% of them explained that the main reason for sleeping with closed windows is not aircraft or traffic noise but fear of burglary.

Another question the residents answered was whether they consider that noise in the neighborhood can lead to the devaluation of their homes. The vast majority, 61%, answered "yes," while 30% answered "no" and 9% of the respondents did not answer this question. The null-hypothesis that more than half of locals consider the devaluation of their homes a reality due to the aircraft noise can be accepted with a great confidence level. Similar studies Conducted by Gjestland *et al*. (2016) showed that many people near airports want to move due to noise, and Suksmith and Nitivatananon (2015) showed that airports have a negative effect in the property value. Thus, it is plausible to say that the belief of devaluation of the homes of people living close to Bacacheri Airport is actually true.

Among the respondents, 64% of them reported symptoms of headache, while 36% stated they did not have this problem. Table 4 lists the reported sources of headache.

Table 4. Sources of headache (Author, 2016)

Sources of headache	Affected individuals (%)
Motor vehicles	32
Airplanes	36
Animals	7
Noisy neighbors	3
Fireworks	3
Nightclubs	2
Others	17

In addition to symptoms of headache, 76% of the respondents reported problems of irritability, while 24% did not feel irritability. Table 5 describes the main sources of irritability.

Table 5. Sources of irritability (Author, 2016)

Sources of irritability	Affected individuals (%)
Motor vehicles	38
Airplanes	35
Toys	4
Animals	2
Churches and temples	2
Others	19

Furthermore, 64% of the respondents residing in the neighborhood reported problems of insomnia, while 36% stated they did not experience this. With regard to this symptom, Tab. 6 lists the noise sources that generate insomnia.

Table 6. Sources of insomnia (Author, 2016)

Sources of insomnia	Affected individuals (%)
Motor vehicles	32
Airplanes	29
Animals	4
Churches and temples	3
Nightclubs	3
Construction works	3
Noisy neighbors	3
Fireworks	2
Others	21

The respondents were asked to indicate the time when sleep is most often disrupted. Table 7 lists the times reported by the respondents when their sleep is frequently disrupted.

Table 7. Times of disrupted sleep (Author, 2016)

Times of disrupted sleep	Affected individuals (%)
Between midnight and 2 a.m.	21
Between 2 and 4 a.m.	20
Between 4 and 6 a.m.	12
Between 6 and 8 a.m.	28
Between 8 and 10 a.m.	3
Between 10 a.m. and noon	3
Between 6 and 8 p.m.	2
Between 8 and 10 p.m.	1
Between 10 p.m. and midnight	3
Did not answer	7

As can be seen in Tab. 7, 28% of the respondents stated that their sleep is frequently disrupted between 6 and 8 a.m. Considering the sample size and applying the central limit theorem to the distribution, Eq. (2) can be used to test if it is reasonable to say that one-third of the population surrounding the Bacacheri Airport feels most annoyed between 6 and 8 a.m.

$$\frac{\sqrt{n}(\bar{R}_n - p)}{\sqrt{p(1-p)}} \cong N(0,1) \quad (2)$$

where p is the tested value, in this case one-third, and N(0,1) a normal distribution with expectation 0 and variance 1. Replacing the variables in Eq. (2) and solving it, the value obtained is -1.62, which is a plausible realization of the event according to the standard Fisher's threshold of α=5%.

This disruption of sleep between 6 and 8 a.m. is explained by the greater number of takeoffs and landings in this time frame, as illustrated in Figure 1. This figure shows a data-logged measurement - a graph showing sound levels as a function of time - which indicates that four takeoffs occurred between 7:08 and 7:22 a.m., which are represented by the peaks in the equivalent sound pressure levels, L_{Aeq}. The measurements, which were taken outside the airport close to the beginning section of the runway, varied from 80 dB(A) to 86 dB(A).

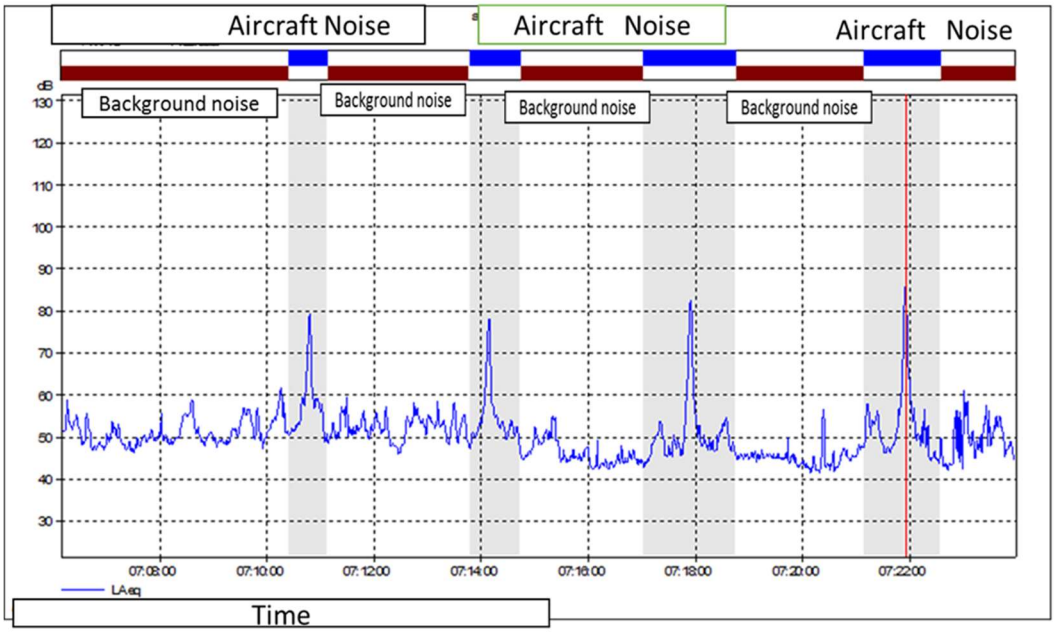

Figure 1. Data-log measurement of the equivalent sound pressure levels, L_{Aeq}, recorded during four aircraft takeoffs (Author, 2016)

Figure 2. Aerial view of Bacacheri Airport and its surroundings (Google Earth, 2016)

Figure 2 shows an aerial view of Bacacheri Airport, highlighting its runway and densely populated surroundings. Figure 3 shows a noise map calculated at the moment of takeoff of an airplane during the daytime, clearly indicating the high sound levels throughout the length of the runway, especially in its central portion, where the maximum equivalent sound pressure levels, L_{Max}, exceed 100 dB(A). The sound measurements for the creation of the noise map and subsequent calibration of the model with the calculated levels were taken at points located inside the airport. Also, note the environmental impact of the very high noise levels caused by aircraft takeoffs on the areas surrounding the airport. It should be kept in mind that takeoffs and landings occur frequently throughout the day, but as can be seen in Fig. 1, air traffic is especially intense in the morning.

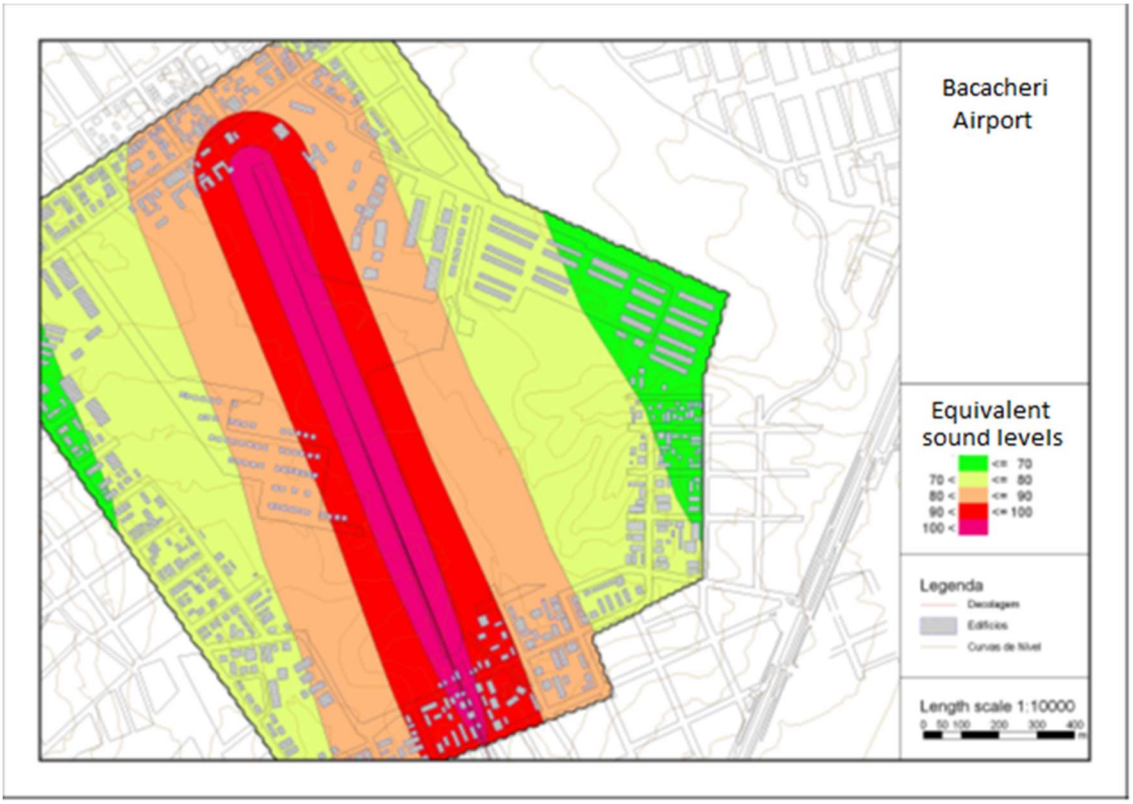

Figure 3. Noise map of a daytime airplane takeoff from Bacacheri Airport (Curitiba, Paraná, Brazil). The colors represent the maximum equivalent sound pressure levels, L_{Max}, expressed in dB(A) (Author, 2016)

4. CONCLUSION

The data presented in this chapter indicate that the 95% confidence interval of individuals around Bacacheri Airport who are aware that noise pollution may be harmful to their health is [79%,93%], which corresponds to the majority of people. Many of the people that live and/or work in the neighborhood state that they are accustomed to noise, and consider it a side effect of living or working in a large and densely populated neighborhood. The data described also indicate that aircraft noise causes headache, irritability and especially insomnia among the residents of the neighborhood.

In addition, the residents of the Bacacheri neighborhood are disturbed not only by aircraft noise but also by road traffic noise, which interfere in their daily lives and affect their quality of life, causing particularly sleep disruption. Among people in the vicinities of the airport, it is plausible to consider that one-third of them complain of disrupted sleep between 6 and 8 a.m., which is precisely the time of peak air traffic at this airport, as indicated by the measurements.

Lastly, the hypothesis that more than half of people around Bacacheri Airport believe that their homes are being devaluated due to noise can be accepted with great confidence. On several occasions in the past, residents and workers of the neighborhood have petitioned the administration of the city of Curitiba to reduce the noise levels in the area, especially the noise generated by the airport.

5. ACKNOWLEDGMENTS

The authors gratefully acknowledge the German Government, through the German Academic Exchange Service – DAAD (Deutscher Akademischer Austauschdienst) and the Brazilian Government, through the National Council for Scientific and Technological Development – CNPq, for their financing of the sound level meters used for the measurements and the acoustic analysis software.

6. REFERENCES

Blais, J., Camier, C., Dufour, M. P., Lapointe, R., Provencher, J., Padois, T., Gauthier, P. and Berry, A., 2013. “Fly-over aircraft noise measurement campaign at Montreal-Trudeau airport using a microphone array”. *The Journal of the Acoustical Society of America*, v. 133, n. 5, p. 3525–3525.

Gerolymatou, G., Remy, N., Vogiatzis, K. and Zafiropoulou, V., 2019. "Assessing Health Effects and Soundscape Analysis as New Mitigation Actions Concerning the Aircraft Noise Impact in Small- and Middle-Size Urban Areas in Greece". *Environments*, v. 6, n. 1, p. 4.

Gjestland, T., Gelderblom, F. B. and Granoien, I. L. N., 2016. "Noise surveys at five Norwegian airports". In *Internoise*, Hamburg, Germany.

Great Britain Department for Environment, 2001. *Towards a National Ambient Noise Strategy: A Consultation Paper from the Air and Environmental Quality Division*. DEFRA, Sydney, 1st edition.

Hygge, S., 2001. *Noise: effects on health*. Cambridge University Press, Cambridge, 1st edition.

Ko, J. H., Chang, S. I. and Lee, B. C., 2011. "Noise impact assessment by utilizing noise map and GIS: A case study in the city of Chungju, Republic of Korea". *Applied Acoustics*, v. 72, n. 8, p. 544–550.

Kurra, S., 2020. *Noise Mapping*. Willey, New Jersey, 1st edition.

Licitra, G., Gagliardi, P., Fredianelli, L. and Simonetti, D., 2014. "Noise mitigation action plan of Pisa civil and military airport and its effects on people exposure". *Applied Acoustics*, v. 84, p. 25–36.

Merino-Martinez, R.; Snellen, M. and Simons, D., 2016. "Determination of aircraft noise variability using an acoustic camera". In: *23RD INTERNATIONAL CONGRESS ON SOUND & VIBRATION*. Athens, Greece.

Murphy, E. and King, E. A., 2010. "Strategic environmental noise mapping: Methodological issues concerning the implementation of the EU Environmental Noise Directive and their policy implications". *Environment International*, v. 36, n. 3, p. 290–298.

Olsen, H.; Liasjo, K. and Granoien, I., *Topography influence on aircraft noise propagation, as implemented in the Norwegian prediction model, NORTIM*. SINTEF, Trondheim, 1st edition.

Suksmith, P. L. and Nitivattananon, V., 2015. "Aviation Impacts on Property Values and Management: The Case of Suvarnabhumi International Airport". *IATSS Research*, v. 39, n. 1, p. 58–71.

Tsai, K., Lin, M. and Chen, Y., 2009. "Noise mapping in urban environments: A Taiwan study". *Applied Acoustics*, v. 70, n. 7, p. 964–972.

Zannin, P. H. T. and Bunn, F., 2014. "Noise annoyance through railway traffic - a case study". *Journal of Environmental Health Science and Engineering*, v. 12, n. 1.

7. RESPONSIBILITY FOR THE INFORMATION

The authors are solely responsible for the information included in this work.