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METHODOLOGICAL PROPOSAL FOR THE CALCULATION OF POPULATION EXPOSED TO AERONAUTICAL NOISE

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Abstract: In Brazil, there are few studies that seek to verify the sound impacts caused by aeronautical noise in exposed communities. To better understand these impacts, this work presents a methodological proposal for the calculation of the population exposed to aeronautical noise around airports. Brasília International Airport (SBBR) was chosen for the study and the exposed population was estimated based on guidelines indicated by the European Community. In the study, census data and acoustic maps were created. As a result, the acoustic maps helped in the identification of areas sensitive to aeronautical noise. It was also possible to estimate and avoid overestimating the size of the population exposed to airborne noise. Attention is drawn to the occupation of areas very close to the limits of the airport site.

INTRODUCTION

Currently, urban centers are in an accelerated process of development, both from an economic and social point of view. Linked to this development, problems and impacts of the most diverse types arise that affect environmental integrity. Therefore, despite the importance of acquiring and maintaining healthy habits to improve the population's quality of life, cities often have environmental characteristics that compromise the development of these activities. One of these issues concerns noise pollution and its power to interfere with the environment and the health of the population (Suriano et al., 2014).

One of the main sources of noise in urban environments is the noise from air traffic. According to Stevens et al. (2010), airports have become a vital component of the transport infrastructure of modern cities, exerting an increasing influence on urban zoning. However, they are also responsible for important environmental externalities, especially noise disturbance and pollutant emissions that contribute to global warming (Carballo-Cruz, 2008).

In this case, airborne noise produces harmful effects on human health, directly contributing to the development of heart problems, stress and sleep disorders (Babisch, 2002; World Health Organization, 2011). Due to the potential for nuisance and damage to health, it became necessary to develop methodologies to better assess the impact of aeronautical noise in inhabited areas around an aerodrome.

The European Community (EC), for example, recommends a methodology based on dose-response models to relate a certain level of noise (dose) with a certain degree of noise nuisance (response/effect). In addition to the use of dose-response relationships, the EC also establishes the mandatory elaboration of acoustic maps and the determination of the estimated number of people affected in different noise ranges (EC, 2002; Directive 2002/49/EC, 2002, WHO, 2011)).

There are no notes in Brazilian legislation on how to methodologically conduct the elaboration of acoustic maps and the calculation of the exposed population. Therefore, the present work presents a methodological proposal for the calculation of the population exposed to aeronautical noise from acoustic maps.

METHOD

In this study, Brasília International Airport was considered (Figure 1), whose acronym ICAO (International Civil Aviation Organization) is SBBR. Currently, the second largest in terms of aircraft and passenger movement in Brazil and, due to its geographic location, it receives and distributes more than 500 flights a day, being considered a connection point for destinations throughout the country and abroad. The growing demand for operations at this airport and its proximity to residential areas point to a situation of compromise of the surrounding sound environment with significant potential for annoyance (Carvalho Jr et al., 2012; Carvalho Jr, 2015).

ACOUSTIC MAPS

Simulations were carried out for the elaboration of the noise curves, in the acoustic metric DNL (day-night level), using the INM 7.0d software. After these simulations, the generated output was exported to a Geographic Information System software where the acoustic maps were prepared following the methodology described in RBAC 161 (2013). For the simulation, several input data were considered, among them: elevation, annual average wind speed, average annual reference temperature, etc. These data were obtained from official government sources or from the SBBR operating company itself. The noise curves generated represent the SBBR operation for 2014, where an estimated 202,000 annual take-off and landing operations were estimated, and an average of 553 daily movements.

METHODOLOGY FOR CALCULATING THE EXPOSED POPULATION FROM THE ACOUSTIC MAPS

The methodology for calculating the population exposed to aeronautical noise was based on the method indicated by the APA (2011) where the calculation must be carried out from the acoustic maps. The exposed populations were calculated for the year 2014 and for the DNL metrics. The following software and database were used to calculate the population exposed to aeronautical noise:

- Geographic Information Software (QGIS)
- Office Package Software: Excel Platform;
- Geometric data of the statistical subsections of the Census Sectors, in shape format (shp) and information for each statistical subsection (data from the 2010 Census of the IBGE - Brazilian Institute of Geography and Statistics);
- Geometric data of the acoustic maps for the DNL acoustic indicator in shape format (shp);
- Extraction of population data from files, in shape format (shp);
- Descriptive manual of the 2010 IBGE Census.

First, the noise curves, generated in the INM, must be superimposed with the census base layer. Then, separate files are created for each noise curve and the intersection of each of the noise curve files with the census database is performed. To do so, in QGIS, select the Vector > Geoprocess > Intersection menus to obtain a new file that has the relationship between the noise level of each curve and the respective census data.

After these first procedures, the census codes must be identified in the census worksheet that indicates the total number of residents per census sector. Thus, in possession of the census code, the value of the DNL indicator and with the total population calculated for each census code, the calculation of the population exposed by noise curve and by AR's was performed.

To avoid overestimating the population data, due to the intersections that could assign equal values to areas between two or more noise curves, it was necessary to calculate the total population of the entire area covered by the largest noise curve and subtract of the results obtained, individually, from each curve. This way, it was possible to identify the calculated value above the total and, thus, obtain the overestimated percentage. It must be noted that this methodology is indicated for when the noise curves are large, as in the case of aeronautical noise, and encompass several census sectors inside, not being necessary the concern to identify the most exposed facade of the buildings (Figure 2A).

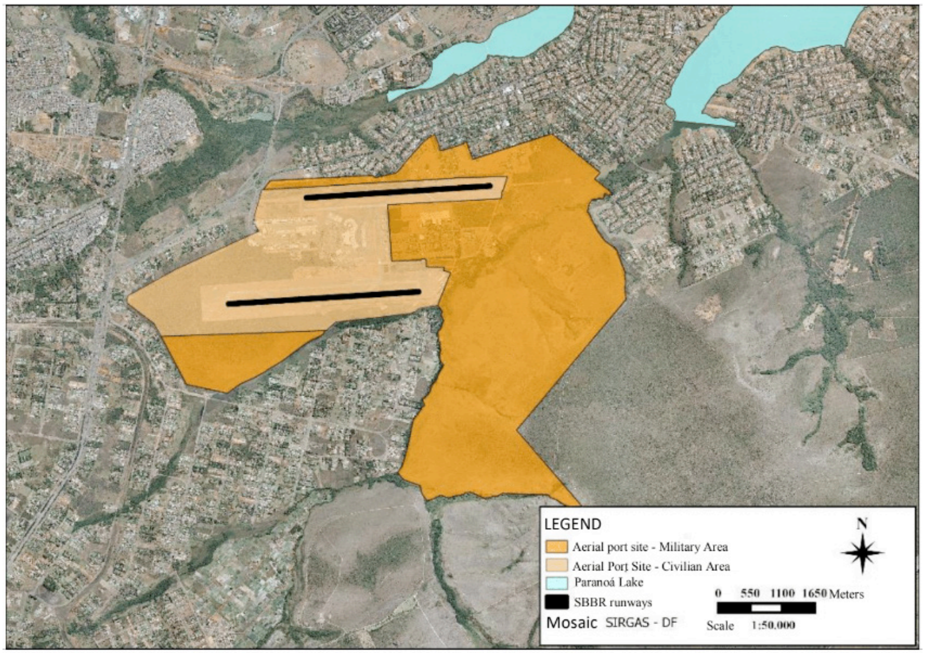

Fig. 1. Location of SBBR

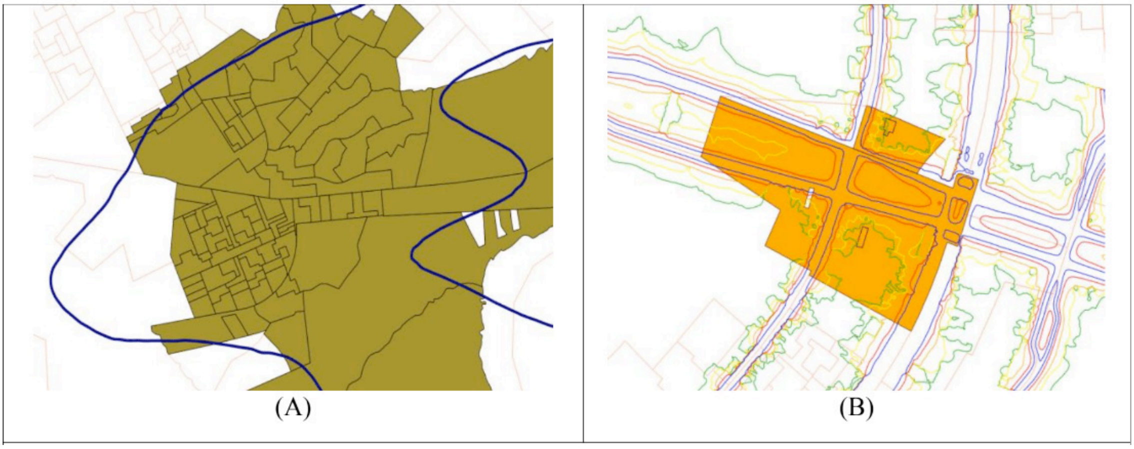

Fig. 2 (A). Census sectors inside aeronautical noise curves (B) Census sectors inside road traffic noise curves

Noise Curve	Limit	Area (km²)
DNL 50	50 <*DNL*≤ 55	186,76
DNL 55	55 <*DNL*≤ 60	92,39
DNL 60	60 <*DNL*≤ 65	44,64
DNL 65	65 <*DNL*≤ 70	15,76
DNL 70	70 <*DNL* ≤ 75	5,31
DNL 75	75 <*DNL* ≤ 80	2,59
DNL 80	80 <*DNL* ≤ 85	0,80
DNL 85	*DNL* >85	0,09

Table 1: Area of DNL noise curves

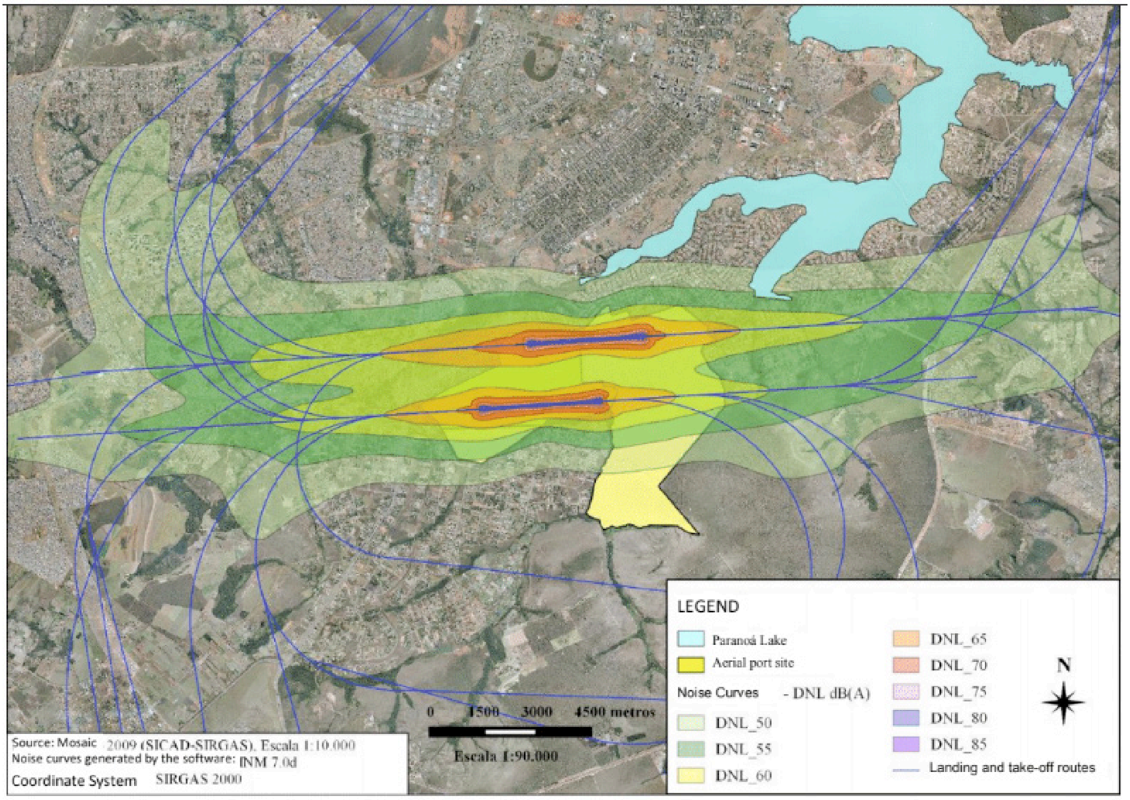

Fig. 3 DNL noise curves and takeoff and landing routes at SBBR

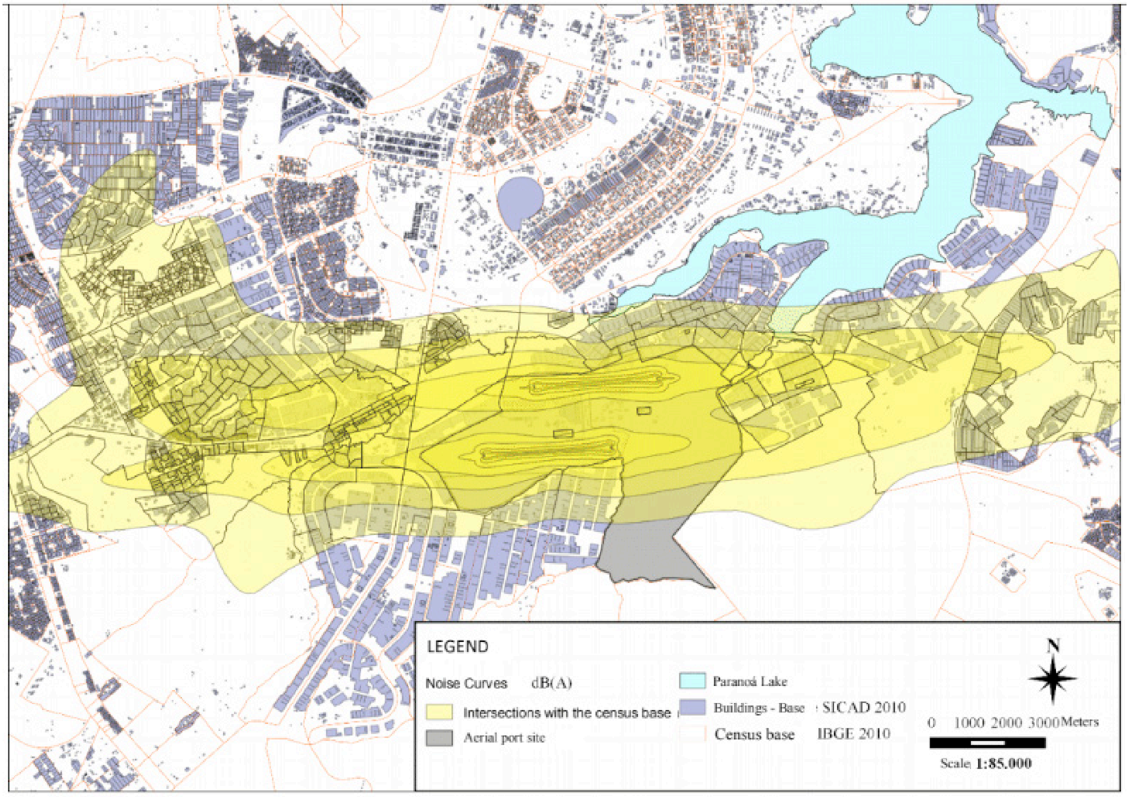

Fig. 4 Intersection of noise curves as the 2010 IBGE census base

However, there is a case where the noise curves are very close to each other, that is, narrower. In this situation, few census sectors are crossed by several of these curves, for example, in the case of road traffic noise (Figure 2B)

This way, each census sector must be selected individually, and the dwellings inside each curve must be counted, paying attention to the identification of the most exposed facades. After this procedure, the number of dwellings is multiplied, per noise curve, by the average value of the number of residents per household, estimated for the census sector under analysis. This procedure was also adopted by Licitra et al. (2012).

RESULTS

Figure 3 shows the acoustic map for DNL 50 to 85 (50 < DNL ≤ 85) and the main aircraft take-off and landing routes at SBBR. To aid in the interpretation of noise maps, Table 1 must be observed, which expresses the limits and areas of each noise curve.

Based on the method presented in Section 2.3, the total population of the area covered by the highest noise curve (DNL 50) was first calculated. Figure 4 shows the result of the intersection of all noise curves, from the DNL 50, with the 2010 IBGE census base.

Table 2 shows the exposed population (PE) and the percentage of the exposed population (%PE) determined. To obtain the values expressed in the PE and %PE columns, the following steps were adopted:

1. Initially, all noise curves were intersected, starting from the DNL 50, with the IBGE 2010 census base in the QGIS software;

2. From this intersection, with the file generated in (1) and shown in Figure 4, the file attributes table was analyzed and the census codes belonging to each DNL curve were identified. With this information, and with the help of the census spreadsheet in Excel, the total population by AR (Administrative Region of Brasília - DF) within these curves was determined.

3. Table 2 presents the total population of each RA (Pop. RA). The PTC1 column, on the other hand, expresses the total values calculated for each curve, with the general total obtained from 577,124 people. No households and residents were identified inside DNL's 75, 80 and 85. These curves are inside the airport site;

4. The result was subtracted from the total population exposed to noise (577,124) and the calculated value of the population exposed only from the DNL 50 (316,741), which encompasses all other curves. The value obtained was 260,383. Here it is worth noting that a large part of the population in the DNL 50, which is 1,054,465 individuals, is not in any noise curve.

5. The overestimated percentage was 45.12% (260,383/577,124). Deducting this percentage from the total population of each RA (column PTC1), column PTC2 is obtained with the first correction of the calculation of the total population estimated by RA and by DNL. The grand total in the PTC2 column is 260,383 which corresponds to the difference made in (4).

6. The DNL's 60, 65 and 70 curves are narrower and do not cover many census sectors. Thus, it was necessary to select (using QGIS) each census sector under these curves, individually, and count the dwellings inside each curve. After this procedure, the number of dwellings was multiplied, per noise curve, by the value of the average number of residents per household (MMPD).

7. The PE column in Table 2 shows the final result for calculating the exposed population.

DNL 50						
RA	Pop. RA	MMPD	PTC[1]	PTC[2]	PE	% PE
I	221.223	2,81	3.623	1.635	1.635	1%
XIX	16.799	3,66	15.858	7.155	7.155	43%
X	125.808	3,09	19.595	8.841	8.841	7%
XVI	31.206	3,57	20.918	9.438	9.438	30%
VIII	23.714	3,24	37.397	16.873	0	0%
VII	45.613	3,65	5.413	2.442	2.442	5%
XXIV	19.759	3,65	13.683	6.173	6.173	31%
XVII	37.278	3,34	46.858	21.141	8.946	24%
XII	220.806	3,59	7.084	3.196	3.196	1%
XIV	97.977	3,58	12.153	5.483	5.483	6%
III	214.282	3,19	134.159	60.529	60.529	28%
Total	**1.054.465**		**316.741**	**142.905**	**113.838**	11%
DNL 55						
RA	Pop. RA	MMPD	PTC[1]	PTC[2]	PE	% PE
XIX	16.799	3,66	10.202	4.603	4.603	27%
X*	125.808	3,09	3.070	1.385	1.385	1%
XVI	31.206	3,57	15.020	6.777	6.777	22%
VIII	23.714	3,24	32.733	14.768	2.609	11%
XXIV	19.759	3,65	9.019	4.069	4.069	21%
XVII	37.278	3,34	59.931	27.039	27.039	73%
XIV	97.977	3,58	5.362	2.419	2.419	2%
III	214.282	3,19	57.139	25.780	25.780	12%
Total	**566.823**		**192.476**	**86.840**	**74.681**	13%
DNL 60						
RA	Pop. RA	MMPD	PTC[1]	PTC[2]	PE	% PE
XIX	16.799	3,66	4.924	2.222	1.428	9%
X*	125.808	3,09	1.203	543	834	1%
XVI	31.206	3,57	8.746	3.946	3.946	13%
VIII	23.714	3,24	21.180	9.556	21.180	89%
XXIV	19.759	3,65	10.141	4.575	3.975	20%
XVII	37.278	3,34	2.380	1.074	1.074	2,9%
III**	214.282	3,19	887	400	615	0%
Total	**468.846**		**49.461**	**22.315**	**33.052**	7%
DNL 65						
RA	Pop. RA	MMPD	PTC[1]	PTC[2]	PE	% PE
XIX	16.799	3,66	712	321	0	0%
XVI	31.206	3,57	5.870	2.648	714	2.3%
VIII	23.714	3,24	2.610	1.178	1.172	5%
XXIV	19.759	3,65	9.254	4.175	701	4%
Total	**91.478**		**18.446**	**8322**	**2.587**	4%
DNL 70						
RA	Pop. RA	MMPD	PTC[1]	PTC[2]	PE	% PE
XIX	16.799	3,66	712	321	0	0.0%

XVI	31.206	3,57	1.024	462	89	0.3%
XXIV	19.759	3,65	1.882	849	40	0.2%
Total	**67.764**		**3.618**	**1.632**	**129**	0.2%
Grand Total			**577.124**	**260.383**	**224.157**	

Notes: Pop. RA (Total population of each RA. Source: PDAD 2013/2014) / MMPD (Average of Residents per Household. Source: PDAD 2013/2014) / PTC1 = Calculated Total Population / PTC2 = first correction of the estimated total population calculation / PE = exposed population / %PE = percentage of the exposed population in relation to the total population (Pop. RA) / * Região da Vila IAPI / ** Região da Arniqueira / I – Brasília / XIX – Candangolândia / X – Guará / XVI - Lago Sul / VIII - Núcleo Bandeirante / VII – Paranoá / XXIV - Park Way / XVII - Riacho Fundo / XII – Samambaia / XIV - São Sebastião / III - Taguatinga

Table 2: Population exposed to aeronautical noise

RA	Pop. RA	*DNL* 50		*DNL* 55		*DNL* 60		*DNL* 65		*DNL* 70	
		PE	% PE	PE	% PE	PE	% PE	PE	% PE	PE	% PE
I	221.223	1.635	1,0	----	----	----	----	----	----	----	----
XIX	16.799	7.155	43,0	4.603	27,0	1.428	9,0	----	----	----	----
X	125.808	8.841	7,0	1.385	1,0	834*	1,0	----	----	----	----
XVI	31.206	9.438	30,0	6.777	22,0	3.946	13,0	714	2,3	89	0,3
VIII	23.714	----	----	2.609	11,0	21.180	89,0	1.172	5,0	----	----
VII	45.613	2.442	5,0	----	----	----	----	----	----	----	----
XXIV	19.759	6.173	31,0	4.069	21,0	3.975	20,0	701	4,0	40	0,2
XVII	37.278	8.946	24,0	27.039	73,0	1.074	2,9	----	----	----	----
XII	220.806	3.196	1,0	----	----	----	----	----	----	----	----
XIV	97.977	5.483	6,0	2.419	2,0	----	----	----	----	----	----
III	214.282	60.529	28,0	25.780	12,0	615**	0,3	----	----	----	----
Total	1.054.465	113.838	11,0	74.681	13,0	33.052	7,0	2.587	3,0	129	0,2

Notes: Pop. AR (Total population of each AR. Source: PDAD 2013/2014) / PE = exposed population / % PE = percentage of exposed population in relation to the total population (Pop. RA) / * Região da Vila IAPI / ** Região da Arniqueira / I – Brasília / XIX – Candangolândia / X – Guará / XVI - Lago Sul / VIII - Núcleo Bandeirante / VII – Paranoá / XXIV - Park Way / XVII - Riacho Fundo / XII – Samambaia / XIV - São Sebastião / III - Taguatinga

Table 3: Estimated exposed population by DNL noise curve

Table 3 summarizes the results obtained, where the noisiest curves can be highlighted:

- DNL 60: In this DNL, the total exposed population is 33,052 individuals. The AR's of Núcleo Bandeirante, Park Way and Lago Sul are the ones with the highest number of people exposed;
- DNL 65: In this DNL, the total exposed population is 2,587 individuals. The AR of Núcleo Bandeirante stands out as the most affected region with approximately 5% of the population exposed, followed by Lago Sul (2.3%) and Park Way (4%).
- DNL 70: In this DNL, the total exposed population is 129 individuals. This number of people is small, but indicates the occupation of areas very close to the limits of the airport site where, according to RBAC 161 (2013), residential projects must have measures to achieve a noise reduction of at least 25 dB.

For the DNL 55 curve, the RAs of Núcleo Bandeirante, Park Way, Candangolândia and Lago Sul have a considerable percentage of exposed population. However, in this DNL, the AR of Riacho Fundo stands out, with 73% of the exposed population. In the DNL 50, Lago Sul, Candangolândia and Park Way stand out again with a significant percentage of population. In addition to these AR's, for Taguatinga (South region) a considerable percentage (28%) of the exposed population was also obtained.

CONCLUSION

With the application of the methodological proposal, it was possible to avoid the overestimation of the number of populations exposed to aeronautical noise. It was also verified that in DNL's 60 and 65 the most affected AR's, with the largest number of people exposed, are Núcleo Bandeirante, Park Way and Lago Sul. Attention is drawn to the occupation of areas very close to the limits of the airport site.

It must be noted that in Brazil there are no guidelines and guidelines provided for the determination of the exposed population. The methodological proposal presented here can be adopted in other studies, as it helps in the identification of noise-sensitive areas, guides the sound zoning and avoids the overestimation of data related to the exposed population. This way, it contributes to a better analysis of the impact caused by aeronautical noise in communities living around airports.

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