THE INFLUENCE OF AIRCRAFT NOISE ON POPULATION'S SLEEP – CASE OF CARGO AIRCRAFTS

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ABSTRACT

Aircraft noise has negative influence on health and on human well-being. This present work investigates the influence of this noise on population's sleep surrounding the airport, especially the one caused by cargo aircrafts. Simulations were done through the Integrated Noise Model (INM) program to determine the Sound Exposure Level (SEL) metric during a passage of an aircraft above a receptor. Through this metric, it was possible to estimate the percent of the exposed population expected to be awakened due to a single event using the curves proposed by the Federal Interagency Committee on Noise (FICON) and the Federal Interagency Committee on Aviation Noise (FICAN). Afterwards, it was estimated the percentage of awakenings due to the passage of N different aircrafts. Three scenarios were studied: all night-time movement at the airport, only the night-time movement of commercial aircrafts and the night-time movement without the take-off operations of cargo aircrafts. Cargo aircrafts have presented high noise levels and higher influence on population's sleep. However, in the case of Viracopos International Airport, the removal of noise contributions of cargo aircrafts did not influence any percentage of awakenings after the passage of N aircrafts corresponding to night-time movement at the airport.

Keywords: Airport Noise, Sleep Disturbance, Cargo Aircraft.

1. INTRODUCTION

The airport noise represents a major problem for the neighboring communities of the airport. The characteristics and impacts of aircraft noise vary, but they are generally influenced by factors such as number of flights, duration, type of aircraft and flight route (Sancho and Senchermes, 1983). Despite all the improvements made by technological development, this type of noise is still an important issue nowadays and studies are needed in the international context.

Noise at high levels can cause health effects on humans and even environmental damage. According to (Bentes e Slama, 2011), the main health effects are speech interference, sleep disturbance and annoyance. Notwithstanding, cardiovascular effects are also important health effects (Clark, 2015). The correlation between the noise level and the effects, however, cannot be characterized so easily. The noise definition as an unwanted sound opens a wide interpretation and thus, a subjective component in its evaluation.

Concerning the sleep disturbance, the way in which noise can affect sleep varies greatly from individual to individual and also over time for each one. The awakening of a person may vary with sleep habits, sleep phase and the intensity of the noise. People living near airports and even near other sources of noise are major victims, especially the elderly and people with psychic or physiological disorder (Nelson, 1987).

Sleep disturbance is a major health problem and it is associated with other problems such as depression, diabetes and cardiovascular problems (World Health Organization, 2009). For this reason, several studies were carried out to evaluate the different types of interference. However, (Pearsons *et al.*, 1989) recommended a better investigation due to the discrepancies between the results obtained in laboratory and field studies.

In 1992, the Federal Interagency Committee on Noise (FICON) (Federal Interagency Committee on Noise, 1992) proposed a curve to estimate the percentage of the population susceptible to be awakened due to a single sound event associated with the overflying of an aircraft that would be measured through the sound exposure level (SEL) metric. Five years later, the Federal Interagency Committee on Aviation Noise (FICAN) (Federal Interagency Committee on Aviation Noise, 1997) recommended a new, more conservative curve for estimate the maximum percentage of affected people also using the SEL metric.

The purpose of this work is to investigate the effect of aircraft noise during the landing and takeoff on population's sleep in the vicinity of the Viracopos International Airport (SBKP), especially the ones caused by cargo aircraft since they are older and noisier in most cases. To do so, noise level simulations are performed using the SEL metric for different critical receptors through the Integrated Noise Model (INM) program. The percentage of awakenings due to a single movement is estimated using both FICON and FICAN relations. Afterwards, it was estimated the percentage of awakenings due to the passage of N different aircrafts for the more conservative relation. Three distinct scenarios are analyzed: current nighttime movement, current nighttime movement without cargo aircraft and current nighttime movement without cargo aircraft departures.

2. SLEEP DISTURBANCE

Sleep disturbance was estimated as the most adverse non-auditory effect of environmental noise exposure by the World Health Organization (WHO) in 2011. Even after an adaptation period, humans exposed to noise during sleep have physiological reactions including breathing, body movements, heart rate, awakenings (Basner *et al.*, 2014). Furthermore, there is a variety of sleep disturbance responses, such as behavioral awakenings, arousals or gross bodily movement (FICAN, 1997).

Therefore, many studies trying to find a relationship between the sleep disturbance and the noise exposure were conducted in laboratories and also in fields. The methods used, however, were

not the same due to the distinctions made between the responses. Additionally, there were data of disturbances from individual events and from cumulative effects.

In 1992, based on statistical adjustment of Pearsons' 1989 and also on both laboratory and field studies (Finegold, 1994), the Federal Interagency Committee on Noise (FICON) established an interim dose-response curve to estimate the percentage of awakenings due to a single event noise level. This single event noise level should be measured through the sound exposure level (SEL) metric. Mathematically, the recommended relationship is expressed in Equation (1).

$$\%Awakenings_{FICON} = 0.000007079 \times SEL^{3.496} \qquad (1)$$

Five years later, the Federal Interagency Committee on Aviation Noise (FICAN) investigated three researches on this topic, namely U.K. study, Los Angeles study and Denver study, and then established a new, more conservative dose-response curve to estimate the maximum percentage of awakenings due to a single noise event. (2) expresses the FICAN relationship.

$$\%Awakenings_{FICAN} = 0.0087 \times (SEL - 1)^{1.97} \qquad (2)$$

It is important to emphasize that this relation considers only the behaviorally awakenings. Also, it should not be apply to children, temporary residences and camps.

3. METHODOLOGY

From the physical information of the airport and the identification of aircraft operations and models, the noise levels represented in the SEL metric were simulated using the INM 7.0 program. As the program database did not feature all aircraft models, some of them had to be replaced by others with similar characteristics. In addition, the noise levels generated in the simulations were reduced by 10 dB (A) to consider indoor environments with open windows, following the NBR 10151 (Associação brasileira de normas técnicas, 2000).

The percentage of awakenings to a single overfly of an aircraft was first estimated using the equation proposed by FICON, (1), and then using the one proposed by FICAN, (2). Afterwards, the percentage of awakenings due to the movement of N different aircrafts according to the night movement at the airport by HOTRAN was also estimated from the results provided by FICAN equation. For this calculus, the following procedure was adopted: first, it was obtained the percentage of non-awakening of each activity, $(\%NA)_{Aircraft\text{-}i}$, as demonstrated in Equation (3):

$$(\%NA)_{Aircraft\text{-}i} = 100\% - (\%A)_{Aircraft\text{-}i} \quad (3)$$

where $(\%A)_{Aircraft\text{-}i}$ is the percentage of awakenings due to the single movement of the aircraft i.

Then, the percentage of non-awakenings due to N movements, $(\%NA)_{total}$, was estimated using Equation (4).

$$(\%NA)_{total} = (\%NA)_{Aircraft\text{-}1} \times (\%NA)_{Aircraft\text{-}2} \times \ldots \times (\%NA)_{Aircraft\text{-}N} \quad (4)$$

Finally, the percentage of awakenings, $(\%A)_{total}$, was determined through Equation (5).

$$(\%A)_{total} = 100\% - (\%NA)_{total} \quad (5)$$

In this work, it was only considered 30% of this maximum percentage. Furthermore, five critical receptors are chosen in regions close to the airport in order to quantify the noise levels at a

specific point as well as the percentage of people who are awakened in it. Their locations are illustrated in Figure 1.



Figure 1: Localization of the critical receptors

Source: (GOOGLE EARTH, 2016).

4. RESULTS AND DISCUSSION

The noise levels represented in the SEL metric obtained through the simulations for each critical receptor are shown on Table 1. They were determined considering indoor environments with open windows for both landing (APP) and takeoff (DEP) operations. The results for cargo aircrafts are written in red.

Table 1: Noise levels represented in the SEL metric, in dB(A), for indoors environments

Aircraft Model	R1		R2		R3		R4		R5	
	DEP	APP	DEP	APP	DEP	APP	DEP	APP	DEP	APP
A319	67,9	57,9	51,8	72,6	74,3	32,9	55,8	47,8	57,7	47,8
A343	72,2	61,6	55,1	75,2	77,4	41,4	59,1	52,5	61,2	52,5
AT45	62,1	50,0	48,6	63,2	63,8	29,7	53,0	41,4	54,3	41,3
AT72	67,8	55,5	56,8	71,6	66,2	31,8	62,0	42,5	62,6	42,7
B737	74,9	61,5	59,3	75,3	77,5	42,3	63,4	52,3	65,4	52,3
B738	76,6	61,2	60,9	74,9	79,4	44,4	65,1	52,0	67,2	52,2
B744	81,1	65,9	65,2	80,2	82,0	50,8	69,5	56,7	71,3	56,7
B748	75,0	68,2	58,3	83,8	83,6	53,5	61,9	55,4	64,0	55,8
B74F	81,1	65,9	65,2	80,2	82,0	50,8	69,5	56,7	71,3	56,7
B752	76,2	60,7	58,5	75,1	71,9	40,9	62,7	50,1	65,0	50,2
B763	79,6	63,0	62,8	77,4	83,6	48,0	67,1	53,6	69,1	53,7
B772	78,8	61,7	62,0	75,4	75,8	44,0	66,6	52,3	68,5	52,6
DC 10	72,1	63,4	55,7	78,2	75,6	48,7	59,7	52,9	61,7	53,1
E170	72,7	60,2	56,9	74,4	75,2	41,6	60,9	50,5	62,8	50,5
E190	67,9	57,9	51,8	72,6	74,3	32,9	55,8	47,8	57,7	47,8
MD 11	77,8	60,3	61,8	74,7	81,1	49,3	66,4	51,6	68,3	51,7

For all five critical receptors the highest noise levels are generated by the cargo aircraft for both landing and takeoff operations. Consequently, their noise curves are also larger, covering a wider area and affecting considerable amount of people. The less noisy aircraft was AT45 commercial aircraft at all receptors, while the noisiest one varied according to receptor and operation.

From these noise levels, the percentage of awakenings was first obtained using FICON curve, Equation (1), and then using FICAN curve, Equation (2). They are, respectively, shown on Table 2 and Table 3. Again, the results for cargo aircraft are written in red and they were higher in most cases. However, the noisiest commercial aircraft showed similar values and even higher when compared with the quieter cargo aircrafts.

Table 2: Percentage of awakenings using FICON curve

Aircraft Model	R1		R2		R3		R4		R5	
	DEP	APP	DEP	APP	DEP	APP	DEP	APP	DEP	APP
A319	18,0%	10,3%	7,0%	22,7%	24,6%	1,4%	9,0%	5,3%	10,2%	5,3%
A343	22,3%	12,8%	8,7%	25,7%	28,4%	3,2%	11,1%	7,3%	12,5%	7,3%
AT45	13,1%	6,2%	5,6%	14,0%	14,4%	1,0%	7,6%	3,2%	8,2%	3,2%
AT72	17,9%	8,9%	9,6%	21,6%	16,4%	1,3%	13,1%	3,5%	13,5%	3,5%
B737	25,3%	12,7%	11,2%	25,8%	28,5%	3,4%	14,1%	7,2%	15,7%	7,2%
B738	27,4%	12,5%	12,3%	25,3%	31,0%	4,1%	15,5%	7,1%	17,3%	7,2%
B744	33,4%	16,2%	15,6%	32,1%	34,7%	6,5%	19,5%	9,6%	21,3%	9,6%
B748	25,4%	18,2%	10,5%	37,5%	37,2%	7,8%	13,0%	8,8%	14,6%	9,0%
B74F	33,4%	16,2%	15,6%	32,1%	34,7%	6,5%	19,5%	9,6%	21,3%	9,6%
B752	26,9%	12,1%	10,7%	25,5%	21,9%	3,1%	13,6%	6,2%	15,4%	6,2%
B763	31,3%	13,8%	13,7%	28,4%	37,2%	5,3%	17,2%	7,9%	19,1%	7,9%
B772	30,2%	12,8%	13,1%	25,9%	26,4%	3,9%	16,8%	7,2%	18,5%	7,4%
DC 10	22,1%	14,1%	9,0%	29,4%	26,1%	5,6%	11,4%	7,5%	12,8%	7,6%
E170	22,8%	11,8%	9,7%	24,7%	25,7%	3,2%	12,3%	6,4%	13,7%	6,4%
E190	18,0%	10,3%	7,0%	22,7%	24,6%	1,4%	9,0%	5,3%	10,2%	5,3%
MD 11	28,9%	11,9%	12,9%	25,1%	33,4%	5,9%	16,6%	6,9%	18,3%	6,9%

Table 3: Percentage of awakenings using FICAN curve

Aircraft Model	R1		R2		R3		R4		R5	
	DEP	APP	DEP	APP	DEP	APP	DEP	APP	DEP	APP
A319	5,82%	3,37%	2,16%	7,18%	7,70%	0,06%	2,93%	1,51%	3,32%	1,51%
A343	7,06%	4,21%	2,79%	7,98%	8,69%	0,68%	3,63%	2,29%	4,11%	2,29%
AT45	4,33%	1,86%	1,63%	4,60%	4,75%	0,00%	2,38%	0,68%	2,63%	0,67%
AT72	5,80%	2,87%	3,13%	6,88%	5,37%	0,02%	4,30%	0,80%	4,45%	0,82%
B737	7,89%	4,18%	3,67%	8,02%	8,73%	0,78%	4,65%	2,25%	5,16%	2,25%
B738	8,43%	4,11%	4,04%	7,89%	9,36%	1,03%	5,08%	2,20%	5,63%	2,24%
B744	9,94%	5,29%	5,10%	9,63%	10,26%	1,99%	6,27%	3,11%	6,79%	3,11%
B748	7,92%	5,91%	3,45%	10,90%	10,83%	2,48%	4,28%	2,85%	4,80%	2,93%
B74F	9,94%	5,29%	5,10%	9,63%	10,26%	1,99%	6,27%	3,11%	6,79%	3,11%
B752	8,30%	3,99%	3,50%	7,95%	6,97%	0,63%	4,47%	1,87%	5,05%	1,89%

B763	9,43%	4,55%	4,50%	8,69%	10,83%	1,54%	5,61%	2,49%	6,16%	2,51%
B772	9,16%	4,23%	4,30%	8,05%	8,17%	0,98%	5,47%	2,25%	5,99%	2,31%
DC 10	7,03%	4,65%	2,91%	8,96%	8,11%	1,64%	3,76%	2,36%	4,23%	2,40%
E170	7,21%	3,88%	3,15%	7,73%	7,98%	0,70%	4,04%	1,94%	4,50%	1,94%
E190	5,82%	3,37%	2,16%	7,18%	7,70%	0,06%	2,93%	1,51%	3,32%	1,51%
MD 11	8,82%	3,90%	4,25%	7,83%	9,94%	1,74%	5,42%	2,13%	5,94%	2,15%

Afterwards, it was estimated the percentage of awakenings as the number of movements increased for each night of the week for three different scenarios using FICAN results. In the first case, it was considered all the movement presented in the airport during the night, that is, the movements of commercial and cargo aircrafts. In the second one, only the movements of commercial aircrafts were considered. Finally, in the third, it was considered the movements of commercial aircrafts and also the landing operations of cargo aircrafts. Table 4 presents the number of night flights for all week.

Table 4: Number of night flights

Number of Night Flights	Sun - Mon	Mon - Tue	Tue - Wed	Wed - Thu	Thu - Fri	Fri - Sat	Sat - Sun
All flights	86	81	87	80	81	80	35
Flights of cargo aircraft	12	8	12	7	7	8	8
%Cargo aircrafts	13,95%	9,88%	13,79%	8,75%	8,64%	10,00%	22,86%

Figures 2, 3 and 4 show, respectively, the results obtained for each scenario for receptor 1. For all scenarios, the evolution of the percentage of awakenings showed an asymptotic behavior, i.e., it increased with the increase in the number of movements until reaching a threshold level (after approximately 40 movements). Even if the number of movements continues to increase, the percentage remains the same. There was not considerable difference of the final results between scenarios. This behavior was also observed for the other critical receptors.

Tables 5, 6 and 7 show the final percentage of awakenings for each night and for each critical receptor. A low variation in the outcome of the percentage can be noted for most nights; only it is significant for the night which had the highest ratio between the amount of cargo and the amount of operations. Therefore, the influence of cargo aircraft is not so great when the cargo rate on the drive is low, regardless of the number of operations. It would be recommended to study and establish the amount of cargo aircraft according to the overall night movement.

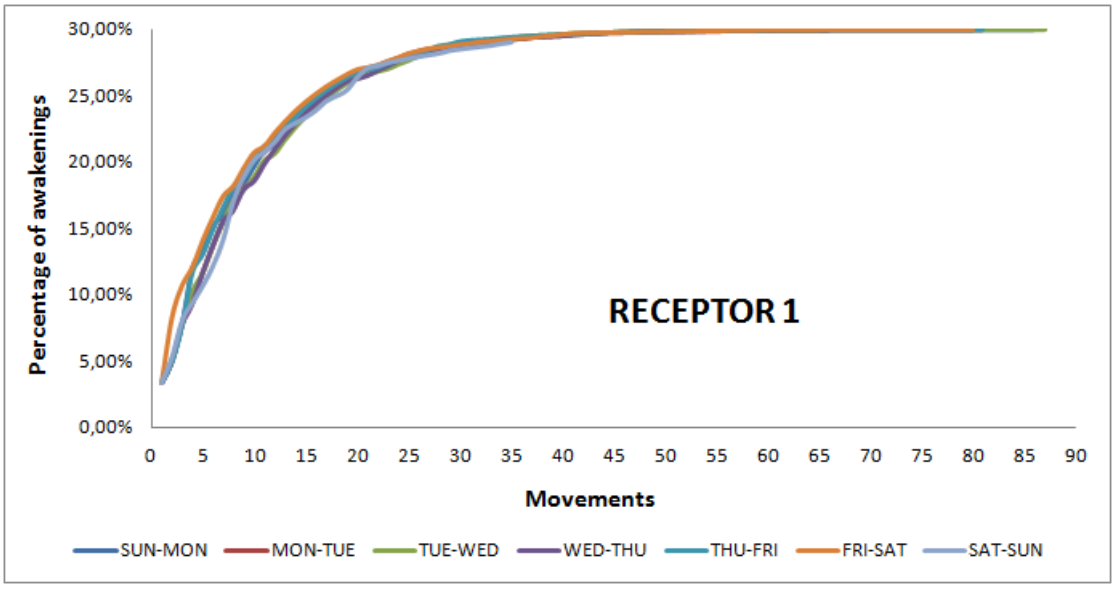


Figure 2: Scenario 1

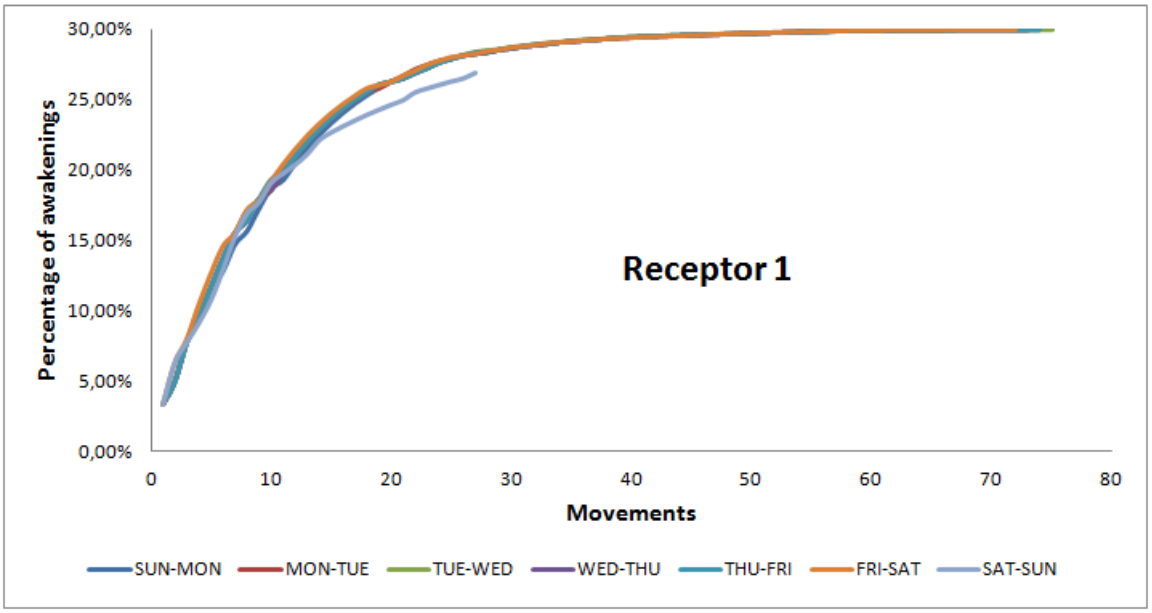


Figure 3: Scenario 2

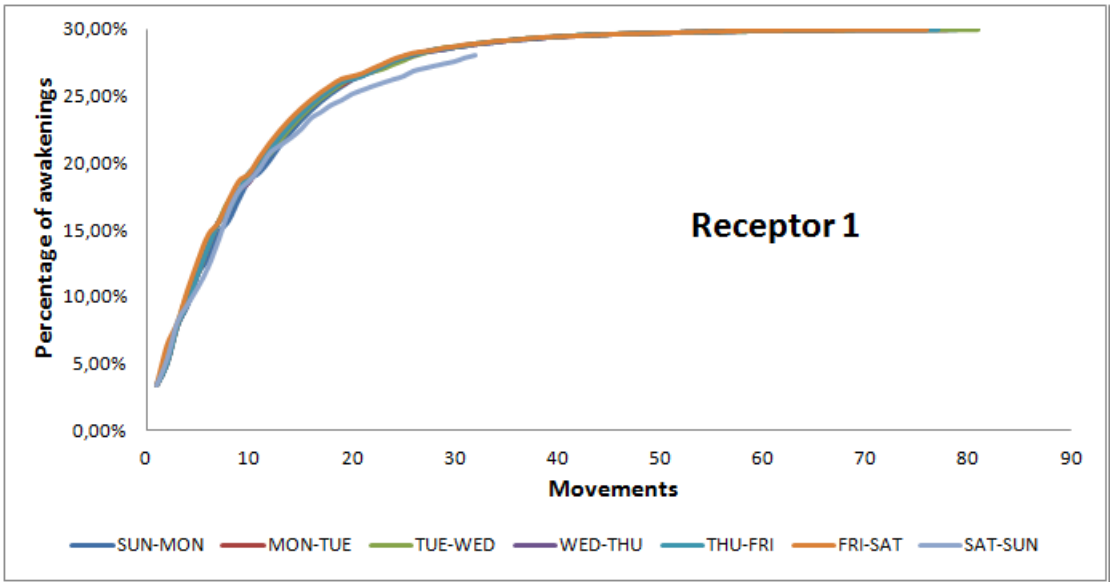


Figure 4: Scenario 3.

Table 5: Scenario 1

Critical Receptor	Sun - Mon	Mon - Tue	Tue - Wed	Wed - Thu	Thu - Fri	Fri - Sat	Sat - Sun
1	30,0%	30,0%	30,0%	30,0%	30,0%	30,0%	29,0%
2	30,0%	30,0%	30,0%	30,0%	30,0%	30,0%	29,6%
3	30,0%	30,0%	30,0%	30,0%	30,0%	30,0%	27,1%
4	29,6%	29,3%	29,6%	29,3%	29,4%	29,3%	23,7%
5	29,7%	29,5%	29,7%	29,5%	29,6%	29,5%	24,4%

Table 6: Scenario 2

Critical Receptor	Sun - Mon	Mon - Tue	Tue - Wed	Wed - Thu	Thu - Fri	Fri - Sat	Sat - Sun
1	30,0%	30,0%	30,0%	30,0%	30,0%	30,0%	27,0%
2	30,0%	30,0%	30,0%	30,0%	30,0%	30,0%	28,7%
3	29,9%	29,9%	29,9%	29,9%	29,9%	29,9%	23,7%
4	28,8%	28,8%	28,9%	28,8%	28,9%	28,7%	19,0%
5	29,1%	29,1%	29,2%	29,1%	29,2%	29,0%	19,8%

Table 7: Scenario 3

Critical Receptor	Sun - Mon	Mon - Tue	Tue - Wed	Wed - Thu	Thu - Fri	Fri - Sat	Sat - Sun
1	30,0%	30,0%	30,0%	30,0%	30,0%	30,0%	28,0%
2	30,0%	30,0%	30,0%	30,0%	30,0%	30,0%	29,5%
3	29,9%	29,9%	29,9%	29,9%	29,9%	29,9%	24,4%
4	29,0%	29,0%	29,1%	28,9%	29,0%	28,9%	21,1%
5	29,3%	29,3%	29,4%	29,2%	29,3%	29,2%	21,8%

5. CONCLUSION

This work estimated the percentage of awakenings in different critical receptors near the International Airport of Viracopos after simulating the noise levels, in SEL metric, generated during the landing and take-off operations of commercial and cargo aircrafts. It was observed that cargo aircrafts do have high noise levels and consequently, the percentages of awakenings due to their activities are also high. However, when investigating the influence of their operations during the whole night, that is, after N aircraft movements, there are no great differences between scenarios with or without cargo aircrafts.

A key point to emphasize is that the effects of the numerous variables in the real case were not considered. For example, some individuals in any exposed population are more sensitive to nighttime noise, while others are less. However, it is a good approximation and opens the opportunity for the development of existing models.

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