

ENVIRONMENTAL IMPROVEMENTS WITH RNP PROCEDURES: THE SANTOS DUMONT AIRPORT CASE

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ABSTRACT

Santos Dumont airport in Brazil presents one of the most demanding operational environments in the world, due to its short runway and the various sets of obstacles existing in its surroundings. Besides that, nowadays the airport is also facing two new challenges: to increase the number of passengers and aircraft movements, in order to accommodate the heavy growth in air transport demand in Brazil, and to handle the noise complaints by the communities around the airport. Given that scenario, this paper will investigate the environmental impact of the recently approved RNP (*Required Navigation Performance*) procedures for this airport. The analysis show that the high precision of the procedures may cause noise impacts to be focused in some communities on the airport surroundings, but also yield relevant improvements in terms of fuel burn and emissions.

Keywords: airport noise, RNP procedures, environmental impact

1 - INTRODUCTION

Santos Dumont airport (SDU) is one of the most important airports in Brazil. Data from the year 2011 show it in the Brazilian sixth position both in terms of aircraft movements (129,629) and in pax movement (8,515,021)¹. However this large number of movements is also yielding noise complaints from the communities living near the airport, since it is located in a heavily populated area in the center of Rio de Janeiro. Moreover, the airport also presents a challenging environment in terms of obstacle clearance for takeoffs and approaches, due to the several geographical constraints existing in its terminal area.

RNP (*Required Navigation Performance*) procedures make use of the area navigation concept (RNAV), which permits aircraft operation without coverage of station-referenced

navigation aids, thus allowing more flexibility on the flight paths definition. The RNP procedures differ from the RNAV ones in the sense that it includes specific requirements for aircraft performance monitoring and alerting, which allows higher lateral navigation accuracy. Those characteristics make this type of procedure to be very well suited for airports like SDU, with several operational constraints.

Given that scenario, this paper intends to depict the overall operational situation for this airport, and present the environmental impact of the recently approved RNP procedures.

2 - ENVIRONMENT DESCRIPTION

SDU airport has a configuration of 2 parallel runways, oriented in a North-South direction. The following table present some characteristics of these runways:

Table 1: SDU airport runways basic characteristics

Runway	Length(m)	Width(m)
02L/20R	1260	30
02R/20L	1323	42

Figure 1 shows the position of the airport, as well as some important points in its surroundings, some level curves depicting the topography and the official airport noise zoning²:

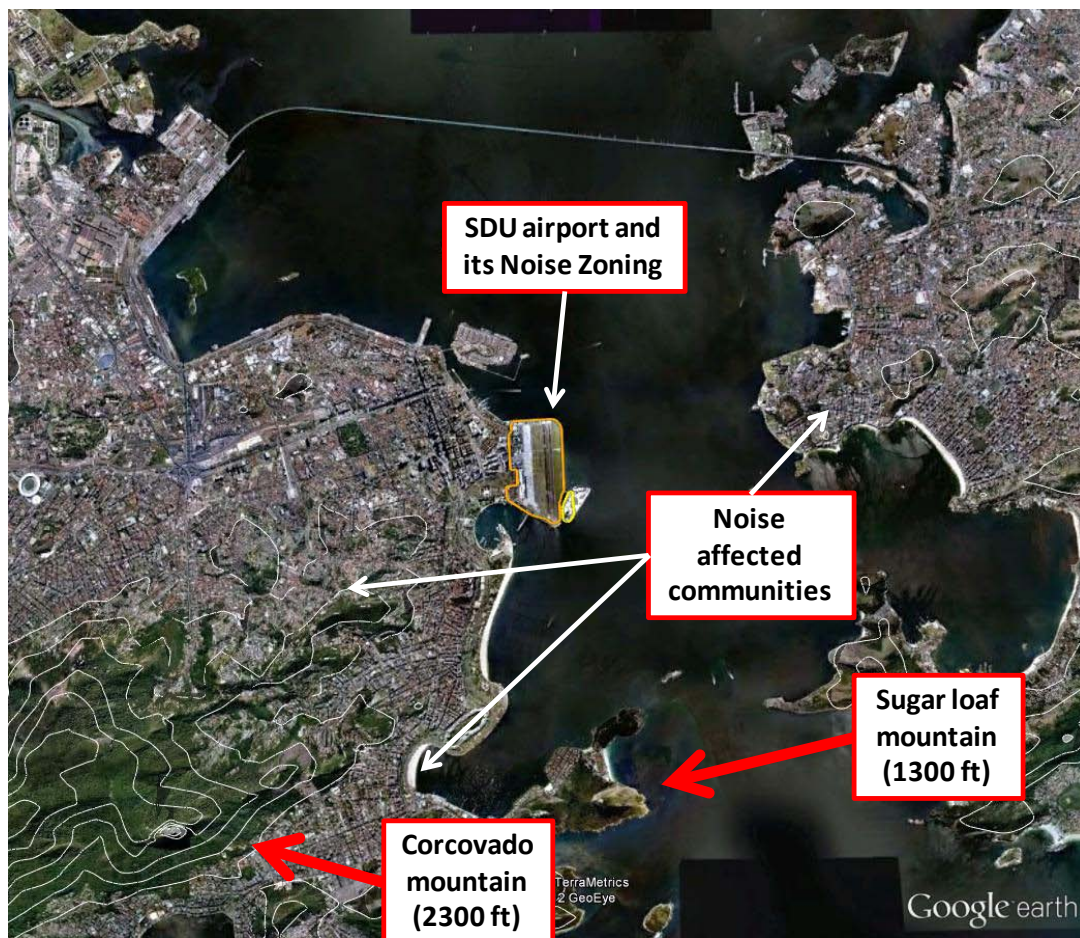


Figure 1 –SDU position in the city of Rio de Janeiro

Figure 1 shows several characteristics of the SDU airport that are relevant for its environmental and operational analysis:

1. The rugged topography jeopardizes the execution of approaches from the south (towards runway 02), since the Sugar Loaf mountain is located straight in front of the final approach line.
2. The topography also potentializes the noise impacts of aircraft operations: some of the affected neighbourhoods are located in higher areas than the airport (which is at sea level).
3. The land areas located near the airport are completely occupied, with several types of land-uses (mainly residential and commercial buildings).
4. Both runways end in the sea, which diminishes the noise impact of takeoffs and approaches because the flight segments close to the airport are performed over water.
5. Due to the position of the runways relative to the sea, depicted in item 4, the official noise curves of the airport are located in inhabited areas.

Despite the noise zoning, which is essentially inside the airport area, several noise complaints are currently being made by the communities close to the airport. These complaints are focused on approaches: due to the irregular topography, runway 02 landings overfly heavily populated areas with higher altitude compared to the airport. In the other hand, most of the runway 20 approaches include a circulation over the east section of the airport, which yields an overflight on the city of Niteroi, on the other side of the Guanabara Bay.

3 - OPERATIONAL DIAGNOSTIC

In order to better understand the current operational situation of the airport, real trajectory data was acquired with the use of an ADS-B (*Automatic Dependent Surveillance-Broadcast*) data receiver and decoder. This survey was performed from 2012, October 6th to 17th, and also in the 27th of July, yielding a total of 788 approaches for analysis. The following table gives details on the runway distribution of these movements:

Table 2 – Runway distribution of the measured approaches in SDU

Runway	Number of approaches	%
02	145	18%
20	643	82%
Total	788	

The following image depicts the spatial distribution of these approaches on the airport surroundings:

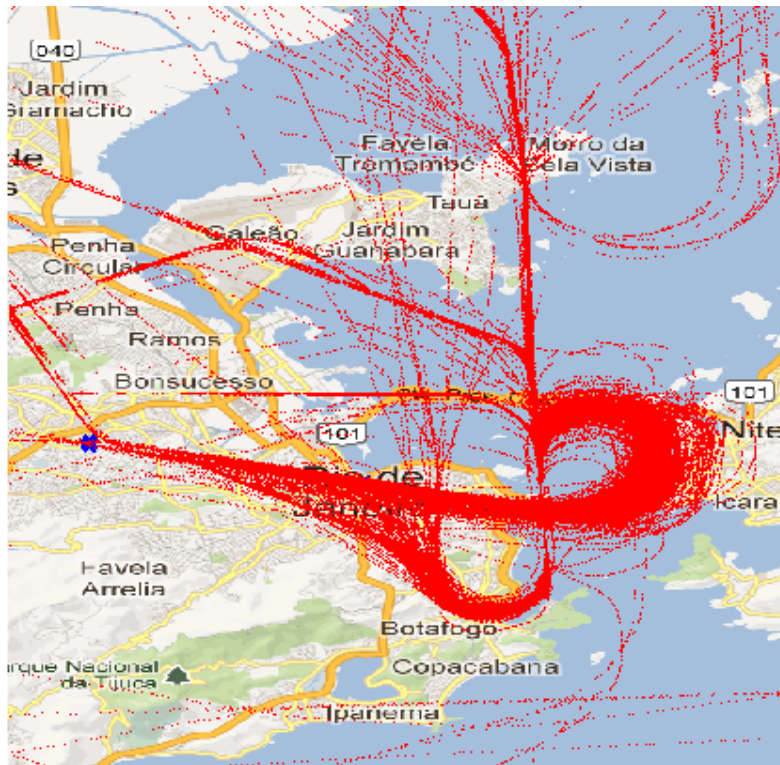


Figure 2 – Measured approaches in SDU airport

For the runway 02 approaches, the image shows the maneuver necessary to clear the existing obstacles, especially the Sugarloaf mountain. In the case of runway 20 approaches, most of the approaches are performed with a circulation on the East section of the airport, in order to avoid interference with the Rio de Janeiro International Airport – Galeão (GIG), located about 13 km northwest.

Currently there are 12 official IAC (Instrument Approach Charts) and a VAC (Visual Approach Chart) for the airport³, which yields the great variety of region overflights seen in Figure 2. Two of the IAC charts define the recently-developed RNP approaches for SDU airport. These type of procedures are part of the Performance-Based Navigation (PBN) concept, currently being evaluated in many countries due to its several advantages when compared with classical sensor-based navigation. According to *ICAO Document 9613 - PBN Manual*, one of these advantages of PBN is that it “allows for more efficient use of airspace (route placement, fuel efficiency and noise abatement)”. This is a direct consequence of the higher flexibility on flight path definitions, which permits a better optimization of the flights depending on the imposed constraints.

Safety and fuel burn are surely the main drivers for the implementation of this kind of procedures, however noise aspects are commonly mentioned to be an issue addressed by the RNP procedures. Thus, the environmental issues are the main subject of the present study.

4 - ENVIRONMENTAL ANALYSIS

4.1 Modelling strategy

In order to evaluate the environmental impact of RNP procedures implemented, all the measured approaches had to be classified in terms of its executed procedure. This classification was performed by identifying the navigation fixes overflow in each approach. Since some of the procedures on the IACs present similar overflight characteristics, which is the relevant variable for the environmental analysis, the approach procedures were classified in 6 types (3 for each runway), defined aiming the inclusion of all the relevant trajectories characteristics for the current study. Details on this division are given in the following table:

Table 3: Defined approach types for the environmental analysis

Runway	Approach type	Description	Number of movements identified	% relative to total movements
02	1	RNAV procedure, as defined in rnav--gnss-b IAC chart.	83	11%
	2	Approach with the overflight of DINA navigation fix, in the center of Rio de Janeiro.	40	5%
	3	RNP procedure, as defined in rnav--rnp--rwy-02r IAC chart.	22	3%
20	1	Approach with circulation over Niteroi city, in the east section of the airport	455	58%
	2	Straight approach from the north	150	19%
	3	RNP procedure, as defined in rnav--rnp--rwy-20l IAC chart.	38	5%

The following image depicts the standard ground track of each of these defined approach types:

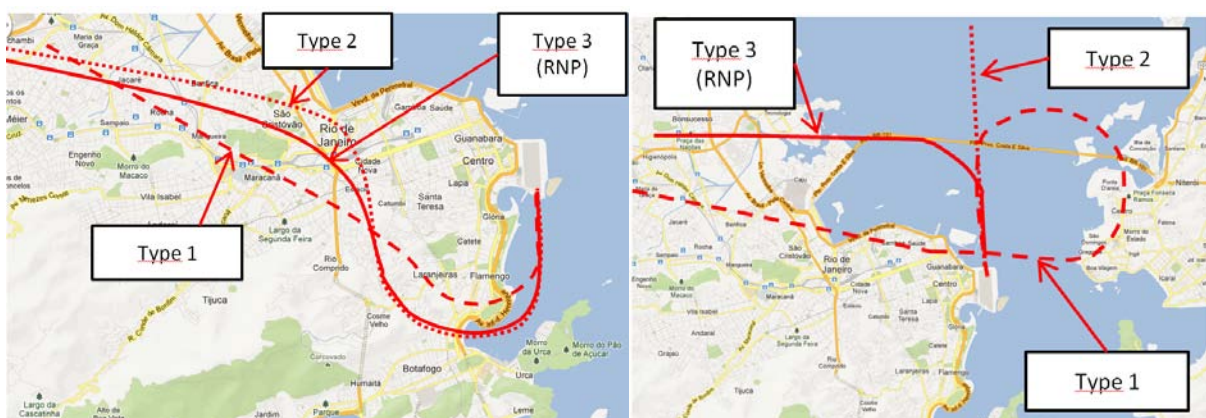


Figure 3 – Approach types defined for environmental analysis, runways 02 and 20

The image show that the RNP approaches at runway 20 are very different from the standard ones, with the removal of the circulation over the east section of the airport. In the other hand, the RNP approach at runway 02 is just slightly adjusted, configuring a similar landing in terms of ground overflight when compared to the other procedures.

All the measured approaches were separated in terms of the defined approach types, with the aid of the navigation fixes used by the procedures. The following images depict the classification into the approach types:

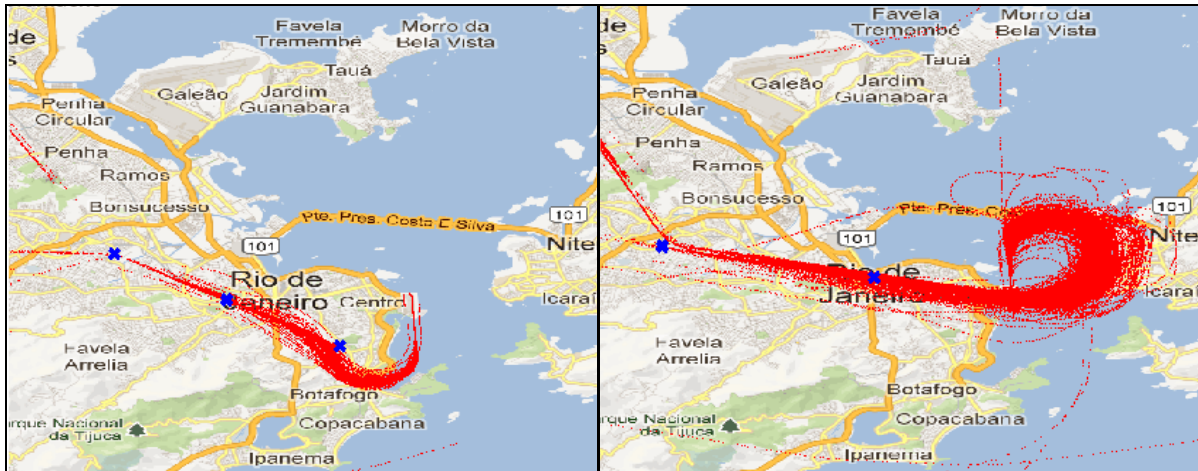


Figure 4 – Identified Type 1 approaches, runways 02 and 20

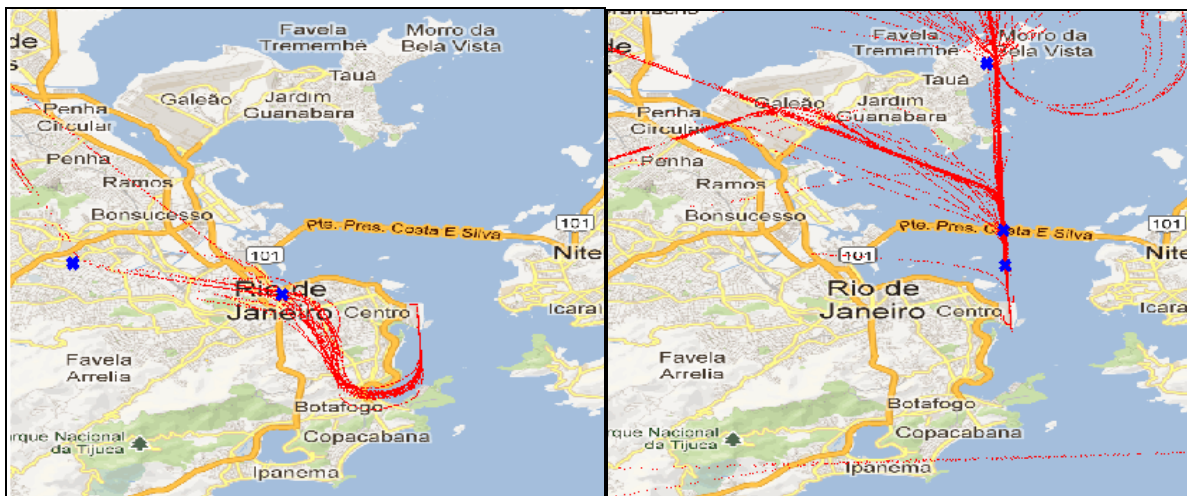


Figure 5 – Identified Type 2 approaches, runways 02 and 20

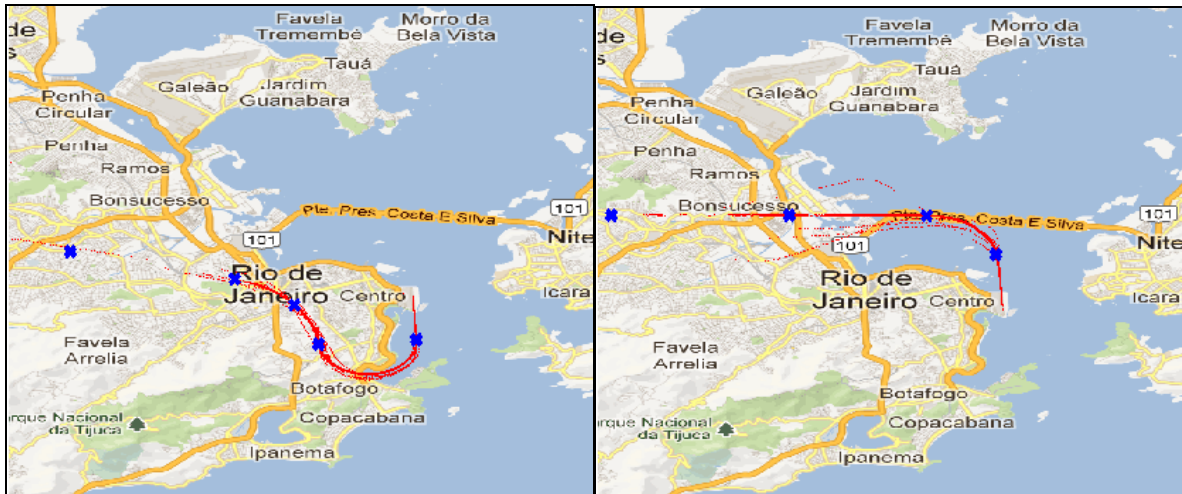


Figure 6– Identified Type 3 approaches (RNP), runways 02 and 20

The data shows that most of the SDU approaches are performed with the overflight of Niterói city. It can also be seen the great precision of the RNP procedures, and consequent small dispersion of the trajectories overflying the RNP navigation fixes.

4.2 Noise analysis

4.2.1 Noise modelling details

In order to assess the noise impacts of the landings in SDU airport, noise maps were evaluated, taking into consideration the operational characteristics of the airport described so far. Some additional premises were used, as follows:

- Since not all the aircraft operating at the airport present the ADS-B capability, it was considered a number of 170 daily landings at the airport, as obtained from the ANAC HOTRAN database⁴ which defines all the regular flights scheduled for the SDU airport. Weekday flights were considered. 13 of these landings occur at the night period (from 22:00 to 07:00).
- Trajectory data from ADS-B were used to define the distribution of the landings in terms of runway and approach type, as well as to evaluate the ground path dispersion of each type of approach.
- Aircraft type considered: Boeing 737-800, currently the most common aircraft operating at the airport.
- Demographic data taken from Brazilian Census of 2010⁵
- Topography data taken from internet-based databases⁶.
- Software used: INM (Integrated Noise Module), version 7.0b
- Noise level used for evaluation: 55 dB DNL

Due to its several advantages, the usage of RNP procedures is likely to increase in the following years, as more aircraft and crew comply with its requirements. The operational scenarios for the noise evaluation were defined with this trend in mind. For the purpose of comparison between the Standard and the RNP procedures, eight scenarios were evaluated: two baseline scenarios, with the current operational situation on each runway, and six scenarios considering all the approaches are performed with the usage of a single type of

procedure. Due to the calculated proportion between the different approach types, the number of movements are not integers. These scenarios are depicted in the following table:

Table 4 – Number of movements considered in each scenario of the noise analysis

Runway	Number of daily approaches	Scenario	Distribution of approach procedures
02	31.3	Current	Type 1: 57%; Type 2: 27%; Type 3: 15%
		1	100% Type 1
		2	100% Type 2
		3 (RNP)	100% Type 3 (RNP)
20	138.7	Current	Type 1: 71%; Type 2: 23%; Type 3: 6%
		1	100% Type 1
		2	100% Type 2
		3 (RNP)	100% Type 3 (RNP)

4.3.1 Runway 20 approaches results

The following images depict the simulation results obtained from Runway 20 approaches. The yellow lines depict the areas subject to noise levels over 55 dB DNL, and the airport surroundings are coloured as a function of the demographical density of each area.



Figure 7: Areas with noise levels over 55 dB DNL: Runway 20 approaches, Current Scenario and Scenario 1

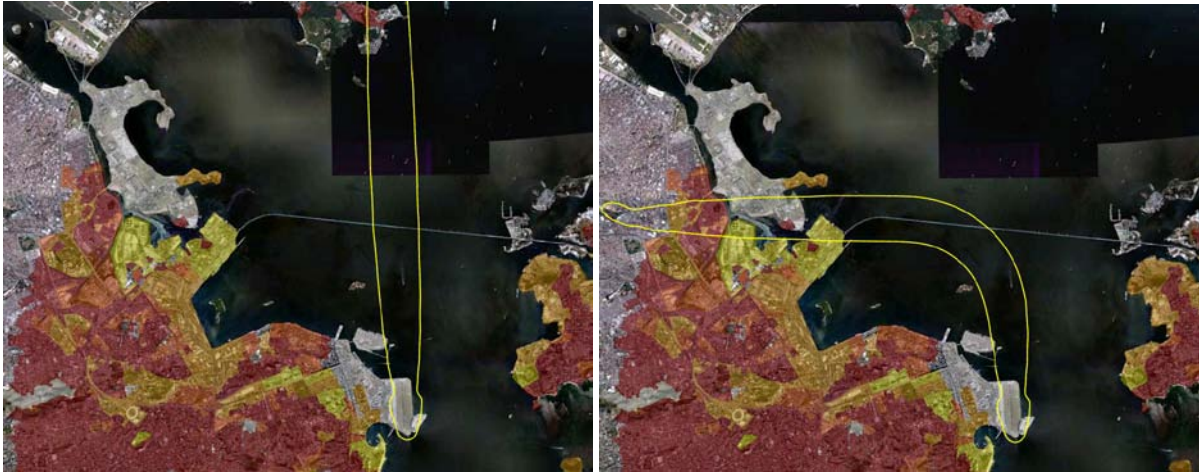


Figure 8: Areas with noise levels over 55 dB DNL: Runway 20 approaches, Scenario 2 and Scenario 3 (RNP)

The image shows that the concentration of flights performing the circulation yields noise levels above 55 dB DNL in some locations of the city of Niterói. However, the dispersion observed on the flights causes most of the noisemap to be overwater.

It can be seen that the noise curves obtained only with the usage of the RNP procedure diverts the noisemap to populated areas on the northwest of the airport.

4.3.2 Runway 02 approaches results

The following images depicts the simulation results obtained from runway 02 approaches:



Figure 9: Areas with noise levels over 55 dB DNL: Runway 02 approaches, Current Scenario and Scenario 1

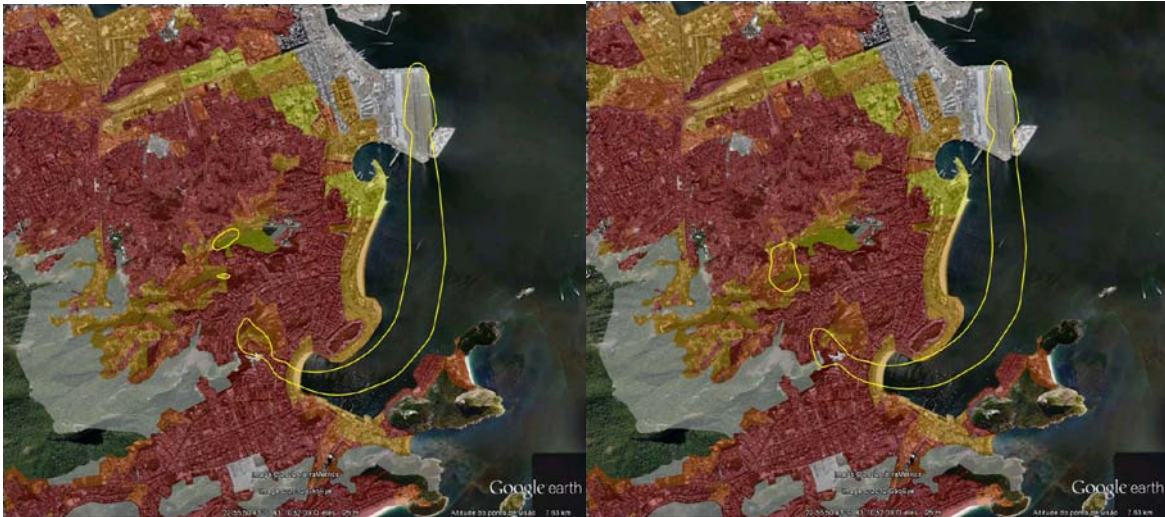


Figure 10: Areas with noise levels over 55 dB DNL: Runway 02 approaches, Scenario 2 and Scenario 3 (RNP)

The images show the influence of the topography on the approach noise perceived close to the airport. The reduction in aircraft-observer distance created by the topography creates the closed noisemaps over 55 dB DNL.

It can also be seen that, due to the very low dispersion observed in the RNP approaches, scenario 3 yields a larger 55 dB DNL area, since all the noise energy gets concentrated in a specific area.

4.3.3 Demographical analysis

The following table depicts the difference between the scenarios simulated, in terms of number of people subject to noise levels over 55 dB DNL:

Table 5: Scenarios analysis in terms of area and people subject to noise over 55 dB DNL

Runway	Scenario	population	area (sq km)
02	Current Scenario	45	2.78
02	Scenario 1	45	2.66
02	Scenario 2	6350	3.12
02	Scenario 3 (RNP)	10159	3.26
20	Current Scenario	974	11.27
20	Scenario 1	2119	15.12
20	Scenario 2	1391	13.41
20	Scenario 3 (RNP)	32495	13.38

It can be seen from the numbers that, in the case of runway 02 approaches, the flight concentration yielded by the RNP procedures and the high demographic density of Rio de Janeiro cause the increase on the number of people subject to noise levels over 55 dB DNL, as opposed to the previous situation, where the spatial distribution of the flights distributes the noise burden over larger areas, thus reducing the cumulative noise level experienced by the communities.

In the case of runway 20 approaches, the usage of RNP procedures redirects the noise map to heavily populated areas currently not affected by overflights, thus yielding the large number of people subject to noise levels over 55 dB DNL.

4.4 Fuel burn and emissions analysis

The rapid growth in aircraft operations observed in the last years yielded concerns on the aviation impact on Local Air Quality and Global Warming. These concerns are being translated into regulations and taxes focused on aircraft emissions, thus bringing attention to the possibilities of aircraft emissions reduction.

In terms of Local Air Quality, there are several air pollutants emitted by aircraft engines that can potentially impact human health and the environment. The most common pollutants considered are Nitrogen Oxides (NO_x), Volatile Organic Compounds (VOC), Carbon Monoxide (CO), Particulate Matter, and Sulphur Oxides (SO_x). Carbon Dioxide emission (CO₂) is also a concern, but in global scope, since it is related to global warming effects⁷.

In the specific case of SDU airport, some characteristics of the city of Rio de Janeiro potentialize the problems related to air quality: rugged topography, sea influence on the distribution and dispersion of air pollutants, high temperatures and a very high demographic density⁸.

Given that scenario, the RNP procedures for SDU airport reduce pollutant emissions mainly due to the reduction of the trajectory distance taken to perform the approach. This reduction causes a reduction in the fuel burn required to perform the flight, thus also reduces the emissions related to the flight.

The following table depicts the approach distance differences between some of the procedures evaluated in this work. For the sake of a meaningful comparison, only procedures which cross each other in at least one point are considered here. This eliminates the procedure 2 of runway 20, since it does not cross any of the other two procedures.

Table 6 – descent distances for the procedures evaluated

runway / procedure	descent distance (nm)
02, 1	10
02, 2	10
02, 3 (RNP)	10
20, 1	20
20, 3 (RNP)	13

In the runway 20 analysis, the RNP approach characterizes a much shorter landing path. In order to estimate the fuel burn gain with the usage of this procedure, an analysis was performed with the usage of the “ICAO Fuel Savings Estimation Tool” (IFSET)⁹, made available by ICAO on its website.

For the analysis, it was considered the same 170 daily landings considered in the noise assessment, and also the same runway distributions between flights. The emission gains were calculated over the actual number of movements using the RNP approach (Type

3), compared to the landings using approach Type 01 (overflights over Niteroi). The following table depict the yearly results obtained:

Table 7 – Fuel burn simulation results, runway 20 movements

Total number of movements	38,821
Number of movements using old procedure (overflight over Niteroi)	35,828
Number of movements using RNP procedure	2,992
Total fuel burn without RNP procedures (tonnes)	11,348
Total fuel burn with RNP procedures (tonnes)	11,041
Descent fuel burn savings (tonnes)	306
Fuel burn improvement	2.7%

In the case of runway 02 approaches, the numbers show that there is no difference in the descent distances when rounded to an integer nautical mile, thus the IFSET software does not foresee noticeable improvements in terms of fuel burn. It should be noted however that RNP procedures also changes the descent flight path in terms of aerodynamical configuration and engine thrust, effects that were not taken into account at this point.

5 - CONCLUSIONS

The situation of SDU airport presents an interesting scenario in terms of environmental impact and operational constraints, due to the topographical and obstacle clearance characteristics. This paper showed that the concentration of flights caused by the new RNP approach procedures for this airport might concentrate the noise impact in certain communities around the airport. Thus, the noise impacts of these procedures shall be constantly evaluated, as their usage increases with time.

In the other hand, the procedures are already yielding important fuel burn and emissions improvements that also have to be taken into account, improvements that will also increase as the procedures get more widely used. This result emphasizes the interdependency between noise and emissions aspects that frequently occurs on operational analysis.

The continuity of this research is aimed at two objectives: first, to improve the noise and emissions modelling by including real performance data of the aircraft currently operating in the airport, in terms of thrust and aerodynamical configurations, as well as taking into consideration the altitude overflight differences between the procedures. This will also allow for a better understanding of the benefits of the procedures, including the economical ones, in terms of airport capacity improvement. Finally, to realize annoyance surveys on the areas pointed out by the noise model, to verify the degree of correlation between the noise modelling and the perceived annoyance by the affected communities.

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