# ANALYSIS OF EMISSIONS FROM THE HANDLING OF AIRCRAFT AT DEPUTADO LUÍS EDUARDO MAGALHÃES INTERNATIONAL AIRPORT

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**Abstract:** The Deputado Luís Eduardo Magalhães International Airport, located in Salvador, Bahia, is the largest and busiest airport in the state, occupying the 10th position in terms of passenger movement in the country. This work analyzed the emissions of atmospheric pollutants from the movement of aircraft in 2017. The FOKKER aircraft, model F100, had lower emissions compared to other models. The AIRBUS aircraft, models A310, 737-800, A320, A330-200 had the highest emissions, this fact is due to the technology and engines more efficient in burning the fuel, aviation kerosene (QAv). This study presents an initial advance, being part of a more complete inventory of sources for the region, and an important tool for stimulating the creation of emission reduction programs at airports.

**Keywords:** Salvador, Airport, aircraft, atmospheric emissions.

# ANÁLISE DAS EMISSÕES PROVENIENTES DA MOVIMENTAÇÃO DE AERONAVES NO AEROPORTO INTERNACIONAL DEPUTADO LUÍS EDUARDO MAGALHÃES

**Resumo:** O Aeroporto Internacional Deputado Luís Eduardo Magalhães, localizado em Salvador, Bahia, é o maior e mais movimentado aeroporto do Estado, ocupa a 10ª posição em movimento de passageiros no país. Este trabalho analisou as emissões de poluentes atmosféricos provenientes da movimentação de aeronaves, em 2017. As aeronaves da FOKKER, modelo F100, apresentaram menor emissão em relação aos demais modelos. As aeronaves da AIRBUS, modelos A310, 737-800, A320, A330-200 apresentaram as maiores emissões, esse fato deve-se à tecnologia e motores mais eficiente na queima do combustível, querosene de aviação (QAv). Este estudo apresenta um avanço inicial sendo parte de um inventário de fontes mais completo para região, e uma importante ferramenta para o estímulo da criação de programas de redução das emissões em aeroportos.

**Palavras-chave:** Salvador, Aeroporto, aeronaves, emissões atmosféricas.

## 1. INTRODUCTION

The growing demand for air transport, especially in Brazil, brings with it the increase in atmospheric pollution functions as a function of the volume of traffic. The technological advances observed in the last few were modified to reduce the efficiency of efficient engines; these advances were not able to compensate for the increase in aircraft [1].

The aviation sector predominantly uses two types of fuel: aviation gasoline (AVGAS) and aviation querosene (QAv). AVGAS is used in small aircraft engines, which can be piston or not and with spark ignition. However, the main fuel used is QAv, mainly in planes with jet engines or pure jet [2].

According to ATAG (Air Transport Action Group), commercial flights generated 676 million tons of $CO_2$ in 2011. 80% of the $CO_2$ came from flights over 1,500 kilometers in distance. For example, according to the ICAO (International Civil Aviation Organization), a plane trip between São Paulo and Miami represents an addition of 960 kilos of $CO_2$ to your carbon footprint. The stretch between São Paulo and Rio de Janeiro, on the other hand, adds 112 kilos [3].

Luís Eduardo Magalhães International Airport, located in the Metropolitan Region of Salvador (RMS), between the territorial limits of the cities of Lauro de Freitas and Salvador, 35 km away from the center of the latter, has two runways: the main runway (headline 10/28), with an extension of 3,005 meters and 45 meters of width and the secondary track (headline 17/35), with 1,500 meters of extension and 45 meters of width. The movement of cargo and passengers places the airport terminal as one of the main take-off and landing movements in the Northeast region of Brazil [4].

The city of Salvador is the third most visited tourist destination in Brazil, being considered one of the top 20 favorite destinations for Brazilians, according to Fundação Instituto de Pesquisas Econômicas - FIPE (2012), which projects, if not an increase in demand, at least a constancy in the movement of passengers to that destination. In addition, the airport ranked first among airports in the Northeast, in 2013, with 4.4% of all takeoffs and landings in Brazil and 25% of total trips made in the Northeast region, according to the Agencia Nacional de Aviação Civil - ANAC (2014) [5,6]. In this way, estimating the contribution of this source of pollutant emission becomes fundamental for the management of air quality, through the inventory survey. [7,8].

The objective of this study is to estimate the level of $CO_2$, $CH_4$, $N_2O$, $NO_X$, CO, NMVOC, $SO_2$ emissions from the movement of aircraft at the Deputado Luís Eduardo Magalhães International Airport during the LTO cycle (Landing and Take Off Cycle), in 2017, whose methodological approach is presented in the following topic.

## 2. METHODOLOGY

### 2.1 Study área

Luís Eduardo Magalhães International Airport handles an average of 25,000 passengers/day, and in high season it reaches 35,000, receiving around 8 million passengers annually. The geographic location is shown Figure 1(a) and Figure 1(b) an enlarged perspective of the airport region.

Figure 1(a). Location of Luís Eduardo Magalhães International Airport

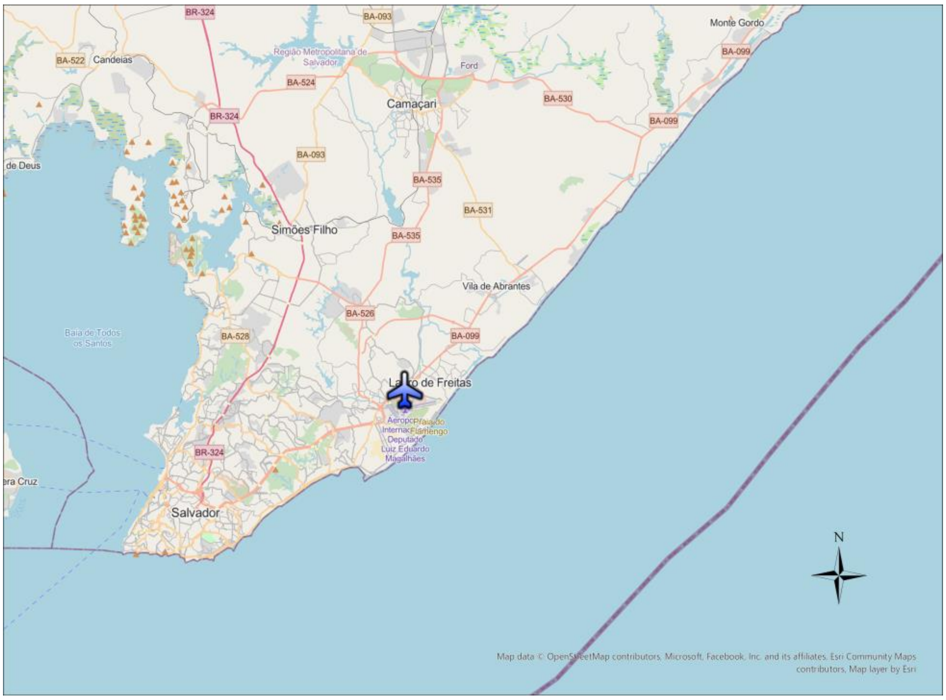
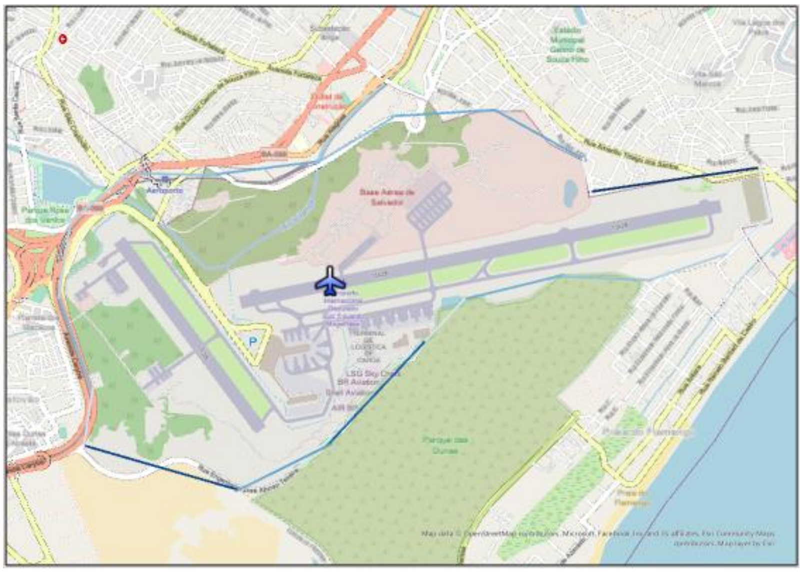



Figure 1(b). Expanding the perspective of the airport region



Source: Made with ArcGis

The airport has an area of approximately 7 million m$^2$ (between dunes and native vegetation), with a complete airport infrastructure with a passenger terminal capable of currently serving 11 million passengers/year and a patio to operate 26 aircraft simultaneously. A striking feature is its beautiful bamboo alley, about 1 km long, at the road access to the airport, which has existed since the late 1940s.

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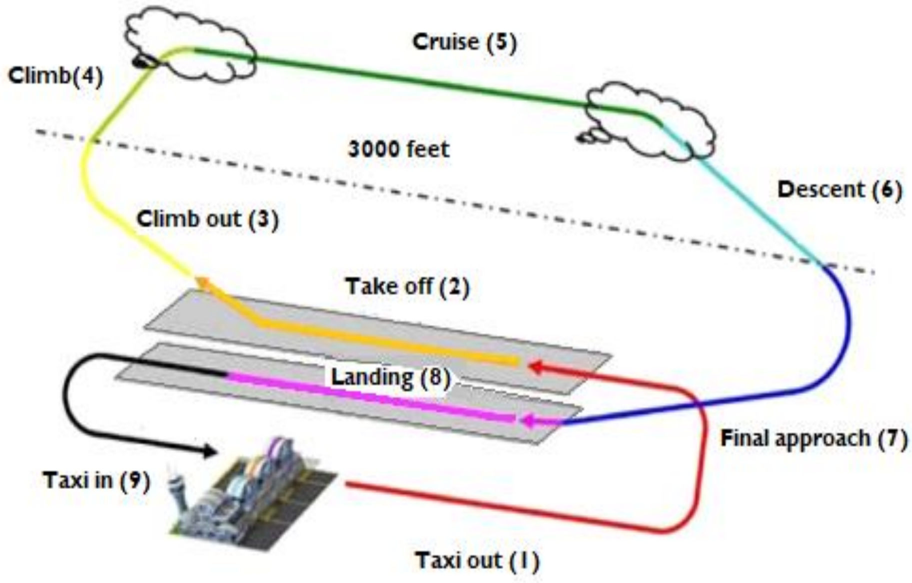
### 2.2 Calculation of emissions by aircraft

The present study adopted a methodology based on the document Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). The source of information on LTO cycles at the airport under analysis was INFRAERO's website on the “flights online” portal. Support activities (internal transport of cargo, passengers, aircraft supply, among others) which are also characterized as sources of pollutant emissions, are not part of the scope due to unavailability of data [9].

Aircraft emissions are calculated separately and are segregated into LTO cycle and cruise flight. In this study, only emissions in the LTO cycle were analyzed, emissions in the cruise phase were not counted, considering the year 2017, in view of the availability of data. The LTO Cycle, or Takeoff and Landing Cycle, includes all activities near the airport that occur below 3,000 feet (914.4 meters) altitude, as shown Figure 2.

Figure 2 - Schematic illustration of the LTO Cycle




Source: INFRAERO, 2017.

The LTO cycle consists of six phases: approach, landing and arrival taxi, engine startup, departure taxi, takeoff and climb, as shown Figure 2. For the calculation of emissions, in addition to the quantification of the number of flights, it was necessary the identification of the types and models of aircraft that performed such operations. The models found were: Boeing 727-200, 737-700, 737-800, 757-200, 767-300; Airbus A319, A320, A321, A330-200; Focker F100; ATR-72; and Embraer EMB145, EMB170, EMB190.

The emission factors used were defined in the IPCC document (2006), and at the 1st Meeting of Lead Authors, in June 2017, in Bilbao, Spain, they started to write the IPCC Refinement, 2019. The final version was considered by the IPCC for adoption/acceptance at its 49th Plenary Session in May 2019 where the pollutants considered were carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), nitrogen oxides ($NO_x$), carbon monoxide (CO), volatile organic carbon – non-methane (NMVOC) and sulfur dioxide ($SO_2$).

Emissions in the LTO cycle are calculated from the fuel consumed in each of the 6 phases. In turn, the fuel consumption in each phase is a function of the aircraft model and number of engines. The fuel flow, calculated as a function of the engine power regime in the phases of flight, are also input data. Finally, the duration of each flight phase is accounted for in the calculation, according to the following equations:

$$C_{a,f,p} = nM_a . Fc_{a,f} . t_{a,f,p} \quad (1)$$

$$E_{g,a,f,p} = Fe_{g,a,f} . C_{a,f,p} \quad (2)$$

Thus,

- ´C´ aircraft fuel consumption ´a´, expressed in kg, for each flight phase ´f´, at aerodrome ´p´;
- ´nM´ number of aircraft engines ´a´;
- ´Fc´ fuel flow in kg/s, of each aircraft engine ´a´ in the flight phase ´f´;
- ´t´ time, in seconds, that the aircraft ´a´ remains in the flight phase ´f´ at the aerodrome ´p´;
- ´E´ emission, expressed in ton (t), of the gas ´g´ by the aircraft ´a´ in the flight phase ´f´ at the aerodrome ´p´;
- ´Fe´ gas emission factor ´g´, in kg $_{gas/kg\ fuel}$, from aircraft ´a´ in phase ´f´.

## 3. RESULTS AND DISCUSSION

Over the last few decades, trade has been globalization and both aviation and maritime transport have registered growth, leading to an increase in emissions. The Deputado Luís Eduardo Magalhães International Airport, accounts for more than 30% of traffic, being a significant source of atmospheric pollutant emissions from this movement.

Figures 3(a) and 3(b) shows the emissions at Luís Eduardo Magalhães International Airport considering the LTO cycles during 2017. The aircraft models in the fleet in this period: A310, A319, A320, A321, A330-200, ATR 72, 737-700, 737-800, 757-200, 767-300, ERJ 190, F100. The pollutants considered are carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), nitrogen oxides (NOx), carbon monoxide (CO), volatile organic carbon – non-methane (NMVOC) and sulfur dioxide. ($SO_2$).

Figure 3(a) shows the total emissions for all pollutants considered in this study, at Luís Eduardo Magalhães airport, in Salvador, year 2017, by aircraft during the LTO cycle. Considering that $CO_2$ emissions in numerical terms are much more expressive than the others, it was necessary to shows the emissions according Figure 3(b) in order to analyze the emission levels of the other pollutants.

Figure 3 (a) – Emissions for each type of pollutant inventoried from the movement of aircraft in 2017 in the LTO Cycle

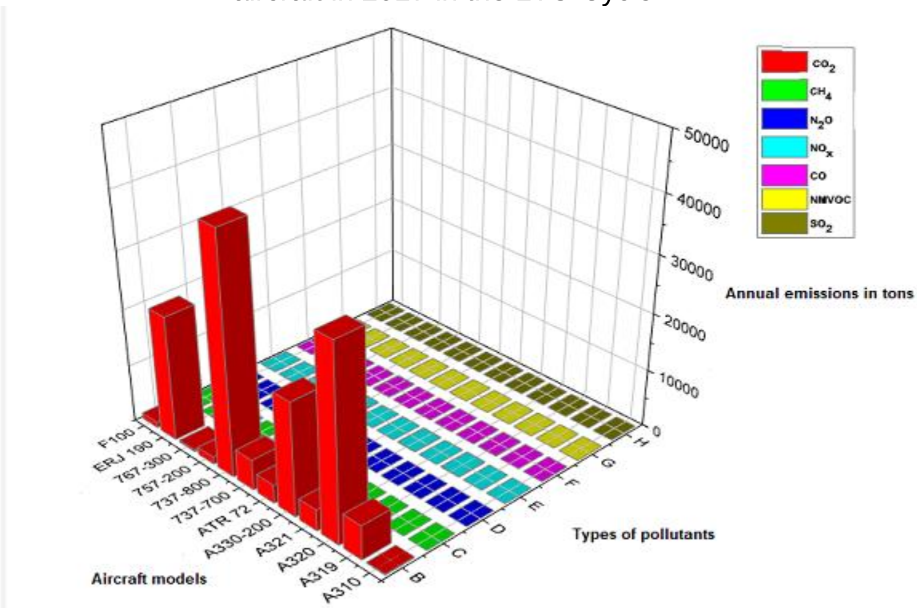
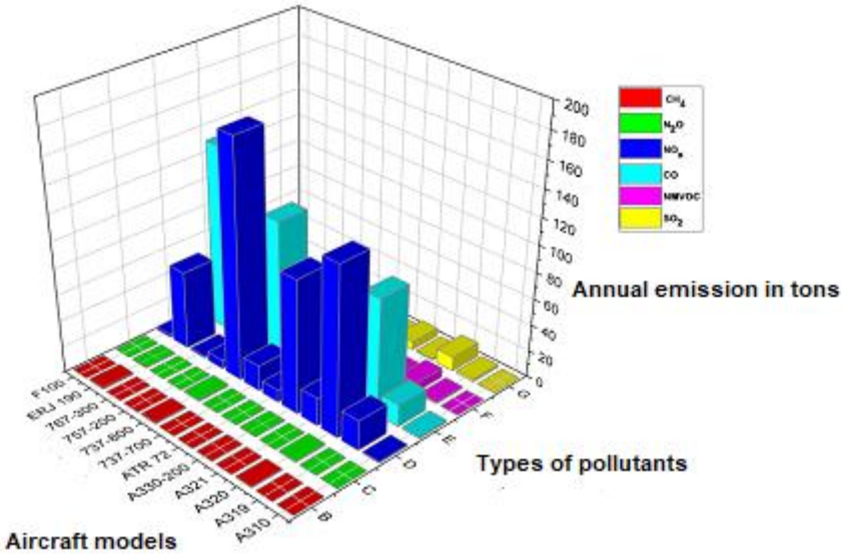



Figure 3 (b) - Emissions from aircraft movement in 2017 in the LTO cycle, disregarding $CO_2$




Source: Own elaboration.

The results obtained showed that aircraft in general emit mostly $CO_2$, $NO_x$ and CO, as shown Figure 3(a) and 3(b).

$CO_2$ at high levels causes heat retention in the lower layers of the atmosphere (greenhouse effect) and directly affects human beings, causing cardiac and respiratory disorders, representing the largest volume of emissions in the LTO cycle. In the analysis of emissions, the volume of LTO cycles performed by each aircraft must also be considered.

$NO_x$ and CO are emissions at intermediate levels when compared to $CO_2$ emissions and $CH_4$, $H_2O$, NMVOC, $SO_2$ emissions. The increase in NOx levels in the composition of the atmosphere causes lung irritation and lung infections, in addition to being a precursor in the formation of tropospheric ozone and CO causes cardiovascular disorders.

$CH_4$, $H_2O$, NMVOC and $SO_2$ were the least representative levels when compared to the other emission levels. Of these, the NMVOC and $SO_2$ stand out. NMVOC causes irritation (respiratory and eye), headache, dizziness, vision and memory problems. $SO_2$, in high concentrations in the atmosphere, undergoes oxidation and hydration, turning into sulfuric acid ($H_2SO_4$), which is one of the acids that make up acid rain. In addition to environmental damage, which directly impacts humans, sulfur dioxide is a toxic gas that causes irritation to the respiratory system, skin and can lead to the development of cardiovascular diseases.

In general, it was observed that the aircraft models that had the highest contribution among the pollutants considered were Boeing 737-800, Airbus A320, Airbus A330-200, Embraer ERJ190. Some factors to be considered in this regard are the fact that the fuel used is still mostly QAv, despite the efforts made at Rio +20 with proposed alternatives such as aviation biokerosene, solar-powered airplanes and the polluter-pays principle. Another factor would be the age of the fleet and on-board technology due to technological advances in the efficiency of aircraft engines.

## 4. CONCLUSION

The calculations performed for the preparation of the inventory of atmospheric pollutant emissions from the Airport took into account only the emissions at the local level (boarding, disembarkation and taxiing on the runway), in which, through daily monitoring, it is possible to obtain the number of LTO cycles for each aircraft, correlating it to the respective emission factors of each pollutant ($CO_2$, $CH_4$, $N_2O$, $NO_x$, CO, NMVOC and $SO_2$). The aircraft models that had the greatest contribution to emissions were Boeing 737-800 ($CO_2$, $NO_x$, CO), Airbus A320 ($CO_2$, $NO_x$, CO), Airbus A330-200 ($CO_2$, $NO_x$, CO), Embraer ERJ190 ($CO_2$, $NO_x$, CO). The emission levels found as well as the aircraft models responsible for the highest levels of emissions are compatible with other airports in other cities in Brazil and the world.

The development of studies like this one is fundamental to stimulate the creation of programs aimed at managing air quality, respecting the resilience of the atmosphere and ensuring the population's quality of life. In future works, it is suggested to complement this study with a detailed estimate of atmospheric pollutant emissions resulting from support activities (use of trucks, buses, tractors, loading and unloading of fuel) necessary for the proper functioning of an international airport. In addition, the inclusion of the transport flow carried by passengers and cargo on arrival and departure from the airport must be considered.

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