

NEUTRALIZATION OF FUEL TANKERING EMISSIONS FOR ENVIRONMENTAL SUSTAINABILITY

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This Capstone Project was prepared and approved under the direction of the
Group's Capstone Project Chair, Dr. Peter E. O'Reilly
It was submitted to Embry-Riddle Aeronautical
University in partial fulfillment of the requirements
for the Aviation Management
Certificate Program

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Abstract

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Title: Neutralization of Fuel Tankering Emissions for Environmental Sustainability

Institution: Embry-Riddle Aeronautical University

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The strategy adopted had verified the impacts of Fuel Tankering by the total value assessment in the Brazilian aviation industry in 2019, recommending practical actions to compensate and neutralize damages caused on the environment.

The importance of sustainability has significantly increased over the past years.

The aviation industry has represented an important pillar helping society to meet their present needs, without compromising the environment and future generations.

The present research had as main objective to verify if the Brazilian aviation industry can neutralize the carbon emissions from Fuel Tankering, a practice of refueling more than necessary to gain financial leverage and be environmentally sustainable.

The selected sample was the domestic Brazilian market, composed of the three biggest airlines in the region which represents more than 90% of the market share.

The results of the study have indicated State taxes in Brazil as one of the root causes for Fuel Tankering practice, financial investments to neutralize the carbon emissions which are not considered by the airlines, and policies for carbon compensation that have not been detailed and cleared in the Brazilian aviation market.

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Chapter I

Introduction

Considering the advances and development of the current society, it has been notable the importance of sustainability in every sector of the economy, including the aviation industry. Over the past years, the focus on sustainability has significantly increased. As aviation has been one of the fastest-growing sources of emissions, it has been reasonable to include sustainable solutions in the equation of the economic savings from Fuel Tankering practice, in a way it could represent gains of credibility for the airlines (Boussauw & Vanoutrive, 2019). For this reason, it has been important to verify the impact of improved Fuel Tankering processes on environmental sustainability.

The fuel expenses in Brazil have been responsible for the highest operational cost for the airlines and, as a result, there has been an ongoing pursuit of the highest level of efficiency (ANAC, 2019). In this context, this study has been focused on the Brazilian aviation market, represented by the data from the three major airlines in 2019, in order to demonstrate the concerns about the Fuel Tankering practice.

The economic savings related to Fuel Tankering practices have led to a negative consequence for the environment through unnecessary extra carbon dioxide emissions. In this context, could part of the savings be used to neutralize emissions? It has been crucial to have sustainable options for the aviation industry. It has also been essential to create methods to go along the global requirements concerning worldwide needs (Child et al., 2018).

Problem Statement

The Brazilian aviation industry has been characterized by its competitiveness and very low-profit margins. It has been vital for airlines to identify every opportunity to reduce costs by becoming more lucrative and financially healthy. Fuel accounting has corresponded for approximately 23% of all airline expenses around the world. In Brazil, fuel costs have been around 30-35% (Paiva, 2021) of an airline's operating expenses. It has been part of airlines' best interests to drive fuel cost down, as much as they can.

Fuel Tankering has been the practice of refueling more than necessary for a flight to avoid or minimize refueling at the destination airport for the next sector. It may offer a lucrative benefit when there has been a notable difference in fuel prices between the departure and arrival airports. On the other hand, it has increased the emissions produced because they have resulted in a higher fuel consumption (Tabernier et al., 2021). However, the negative effects on the environment have not been considered as they should have been.

There have been currently multiple programs around the world related to carbon taxes and carbon offsetting, such as EU-ETS in Europe, National Chinese ETS in China, and ICAO's CORSIA for aviation related emissions. Brazil, on the other hand, has considered to be yet an unregulated carbon market (Moss Earth, 2021). The carbon credit purchase has been transitory. It has been a tangible measure for aviation industry while more definite and expensive projects have received proper incentives in order to become economically attractive, such as biofuels.

Purpose Statement

In the Brazilian fuel scenario, each State applies its own tax rates, named ICMS. This has been the tax on the circulation of goods, interstate and intercity transportation and

communication services. It has been considered outdated in terms of tax collection if compared to the economical, technological, and social advancements since its creation (Rodrigues, Melina, Pacheco, 2018). It has an important role in the final value of the aviation fuel in the market, as taxes values may vary significantly amongst the different States (Fregnani, Müller, Correia, 2013) leading to the Fuel Tankering practice.

In the past, a few studies have presented only the economic benefits of Fuel Tankering. They have not considered the practical actions to compensate the damage caused to the environment (Tabernier et al., 2021).

This research project has:

- Assessed the total Fuel Tankering quantity data used by Brazilian airline industry in 2019;
- Explained the total carbon emission that was emitted in 2019 related to Fuel Tankering;
- Appraised the average cost of carbon to neutralize the Fuel Tankering used in 2019 by purchasing carbon credits;
- Recommended support solutions for the adjustment of savings incorporating the neutralization of carbon emissions;
- Evaluated and compared the Brazilian Fuel Tankering scenario against the global scenario.

Project Goals and Scope

The overall objective of this research has been to create an awareness that due to external factors, Brazilian airlines have been polluting the environment in one of the most expensive and

tax-complex countries. The Brazilian airlines, customers, employees, and society have been affected by this practice. Although the participation by the airlines to global warming has been considered to be quite small, the fuel consumption factor has been expected to increase due to the promising rates in the sector (Scheelhaase, 2020).

Uncontrolled greenhouse gas emissions have resulted directly or indirectly, in global climate change, (e.g., changes in weather conditions, global warming, worsening of air quality, water depletion, impaired soil, changes in agriculture and living conditions, etc.) and it has affected human health as well-being and various ecosystems (Andrejiová, Grincova & Marasová, 2020). Recognizing the importance of sustainability has been the result of an organization's perception of being responsible for the impact it has on all stakeholders. On the other hand, a stakeholder perspective has encouraged changes in business thinking to incorporate social principles. Corporate social responsibility has been encouraging more airlines to identify opportunities to create value for its partners in the long term (Prahalad & Ramaswamy, 2004).

The amount of carbon emission produced by the Brazilian airlines has never been revealed in total numbers. This unknown amount should create questions from the airlines, sustainability groups inside the organizations, customers, and the population in general.

This research has analyzed the Fuel Tankering practice that can be performed sustainably.

By showing the importance of the subject, this research has recommended sustainable national measures. The study compared global practices for minimizing the impact of the higher emissions due to Fuel Tankering.

Research Questions

In this context, the research problem of the study has been: Can the Brazilian aviation industry neutralize the carbon emissions from the Fuel Tankering practice that they have produced and thus be environmentally sustainable?

This research has aimed to answer several important questions:

1. What has been the total Fuel Tankering quantity used by Brazilian airline industry in 2019?
2. What has been the negative impact on the environment caused by the practice of Fuel Tankering during 2019?
3. Has it been possible to perform Fuel Tankering sustainably?

Definition of Terms

Fuel Tankering	Fuel Tankering has been a practice whereby an aircraft carries more fuel than required for its safe flight in order to reduce or avoid refueling at the destination airport (ICAO, 2014) or, in other words, fuel transported from point of departure to destination for cost savings, convenience, or follow-on mission requirements, but not designated for burn on current mission leg (U. Walter J. Lesinski III, 2011).
Carbon Credits	Carbon Credits have been certificates that represent the reduction of emissions into the atmosphere. By purchasing them from more efficient industries, companies can neutralize emissions that cannot be eliminated (Blaufelder, Levy, Mannion & Pinner, 2021).

List of Acronyms

ANAC	National Civil Aviation Agency
CBIO	Decarbonization Credits
CNPE	National Energy Policy Council
CO ₂	Carbon Dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
ECAC	European Civil Aviation Conference
ETS	Emission Trading System
EU ETS	European Union Emission Trading System
GHG	Greenhouse gas
HOTRAN	Transport Schedule
IATA	International Air Transport Association
IenvA	IATA Environment Assessment
ICAO	International Civil Aviation Organization
ICMS	Tax on Circulation of Goods and Services
INAIR	International Conference on Air Transport
iNDC	Intended Nationally Determined Contributions
KG	Kilograms
Renovabio	National Biofuels Policy
SBTi	Science Based Targets Initiative
UNFCCC	United Nations Framework Convention on Climate Change

Plan of Study

Chapter Two: Literature review on Fuel Tankering and aviation sustainability in global scope compared to the national scope and current practices.

Chapter Three: Research methodology to calculate the data concerning the total amount of Fuel Tankering used by the Brazilian airline industry in 2019. By filtering only domestic flights, the study has aimed to assess the average cost to the environment of carried fuel and the cost to neutralize the emissions.

Chapter Four: Results for the total amount of Fuel Tankering carried out in 2019 have been presented with the consequences related to total carbon emission and the possible cost for the neutralization of carbon.

Chapter Five: Discussions and implications for more sustainable operations in the Brazilian scenario comparing to an international scenario, recommending further studies for improvements.

Chapter II

Literature Review

Fundamentally, by long-term analysis, the demand for commercial aviation has been driven by economic activity. Noting factors such as emerging middle-class in developing countries, demographic outlook, aviation market liberalization, and climate change, global commercial passenger traffic is expected to growth 3.2 % per year until 2039 (IATA, 2021). South America has been considered an untapped potential. Such factors as economic advancement and its natural characteristics that often hinder travel connectivity by other modes, such as road and trains, in South America has been forecasted for air travel to grow by 5.1 % per year for the next 20 years (Boeing, 2020).

As the aviation industry has been facing a continued expansion, it has played a significant role in the economy. Regarding aviation, it has been essential that each country realize that reducing the emission of greenhouse gases would be a common goal. Achieving such results would be important to the growth of the air transport sector (Andrejiová et al., 2020).

The global tendency of a greener and more environmentally friendly economic growth has collided with the still unavoidable common practice of Fuel Tankering. Most of the studies have correctly understood that Fuel Tankering has not been environmentally friendly. The focus of such studies has been primarily on the economic advantages. Currently, there has been no relevant program for recompensing the negative impacts from carbon emissions. (Tabernier et al., 2021). This practice has been very significant, as the emphasis would be on a relevant and avoidable extra carbon emission (Bailey, 2019).

The literature used for this research project has been subdivided into categories shown below:

- Fuel Tankering and its economic savings
- Environmental sustainability
- Current “methodologies” for minimizing Fuel Tankering

Fuel Tankering and Economic Gains

Fuel Tankering has been globally used in the aviation industry. It has been defined as the practice where an aircraft departs with more fuel than the required quantity to reach the destination, aiming to reduce or avoid the next refueling process (Eurocontrol, 2019). According to Tabernier et al. (2021), it has been mostly used to get around the differences in fuel prices. In the Brazilian scenario, the fuel prices have been most influenced by the tax rates named ICMS. They have been defined independently by each State.

Studies have been carried out in the past identify ways to go along with the price differences. The environmental negative impacts have been mentioned in the majority of the studies, but the Fuel Tankering practice has been considered as “an evil” but necessary. On the other hand, the existing analysis has been focused on searching for the best and most efficient way of performing it.

Our research group has understood that economic savings on Fuel Tankering practice would not be a concern if the factors that influence the use of Fuel Tankering would not exist. Today, there have been software programs for calculating the amount of extra fuel carried for each sector in order to be economically advantageous (Tabernier et al., 2021). This study has proposed recommendations that were given for consideration of the ideal scenario for aviation to cause minimal impact to the environment. Instead of studying the ways to use it wisely, the intent of the study has not been to use it in the first place. Sustainability has been a subject

growing in importance. Public pressure and the planet have required actions for less carbon emission immediately.

Environmental Sustainability

Environmental sustainability has been a subject that is currently part of all industries' concern. It has been defined as the equilibrium of the interaction of the human with the ecosystem, while fulfilling the human necessities without affecting the natural regeneration of the environment (Morelli, 2011). Greenhouse gas (GHG) emissions have been the main driver for the Paris Agreement. This global agreement has been composed in 2015 with the idea of limiting the emissions while attempting to control the global warming (Tribett, Salawitch, Hope, Canty & Bennett, 2017). The participating countries were willing to reduce them by 80% by the year 2050 (Erickson and Brase, 2019). Carbon emissions from aviation have increased significantly for the past decades. They have been expected to continue increasing at 3 to 4 percent per year (Metz et al., 2007).

In recent years there has been an increase in the demand for companies to market their products and services with a green and ecologically correct result. This has been associated with their organizational social responsibility strategy. There have been a few studies that have evaluated the effects of this new environmental demand and its impacts on airlines (Hagmann, Semeijn, and Vellenga, 2015).

Current Methodologies for Minimizing Fuel Tankering

There have been existing programs and initiatives aimed at reducing aviation CO₂ emissions around the world, as well as their impact on climate consequences (Scheelhaase,

Maertens, Grimme & Jung, 2018). Those emissions have been treated both regionally and globally by different agencies. In the European continent, the aviation-focused EU ETS has aimed at a more sustainable future by creating financial incentives for reducing emissions. In addition, the Agency has worked on setting an emission goal for the gradual reduction of emissions (Eurocontrol, 2021).

In a broader approach, ICAO's CORSIA has focused on a global scope and offsetting emissions. Starting in 2020 and using that year as a reference line for future emissions, this program has different stages for participating countries. The main idea has been based on allowing the purchase of carbon credits from different and more adaptable industries. (Scheelhaase et al., 2018).

A voluntary program that has been created to perform a benchmark among airlines, sharing green actions was the IATA Environment Assessment (IenvA). Based on three criteria elements (daily operational activities, corporate environmental management practices, and corporate policies/ strategic planning) the program has helped:

- to identify and implement innovative practices and processes, promoting sustainable environmental management in organizations (Abdullah et al., 2018);
- to divide in two stages, with the participation of third parties;
- to conduct a consultancy, analyzing and ranking green airlines, which achieve the standards to be registered on the program (IATA, 2021).

Summary

The existing literature concerning Fuel Tankering and environmental sustainability has been quite limited. The approaches to Fuel Tankering have considered their economic savings for the airlines and the most efficient way of using it. The programs and policies for reducing the greenhouse gas emissions have been developed and emerged across the globe (Hagmann, Semeijn & Vellenga, 2015). However, Brazil has seemed to be in an outdated position. Brazil has been one of the participating countries of the Voluntary Phases of CORSIA (ANAC, 2019). This means ANAC has conducted the data monitoring, reporting and verification of the operators' CO₂ emissions for international flights from and to other participating countries (ANAC Ordinance 496/2018).

In order for Brazil to keep up with global actions in reducing emissions and regulating the carbon credit market, CNPE Resolution 8 from August, 2020, has been instituted by Law 13,576 / 2017 of the National Biofuels Policy (RenovaBio). The program has emerged in December, 2019 as a long-term public policy with annual goals to structure the sector. One of the proposed instruments has been the Decarbonization Credit (CBIO), an agreement granted by licensed companies that have produced or imported biofuels (Mena Report, 2020).

The situation concerning the Brazilian scenario has been the State taxes and other factors that encourage the airlines to maintain their use of the Fuel Tankering for being financially solid and competitive. According to Tabernier et al (2021), 90% of the Fuel Tankering applied in Brazil has been influenced only by fuel prices. There has been no global nor local program involving the domestic flights in the Brazilian territory. This has resulted in the indiscriminate CO₂ emissions that counter the direction of the global path of sustainable and green consciousness.

Chapter III

Methodology

Concerning the purpose of this study, the Research Team collected data from the three largest airlines in Brazil. These airlines represented approximately 92% of the Brazilian domestic market share in 2019 (ANAC, 2019). Since the pandemic strongly affected the flights and the statistics related to 2020, the Research Team believed that the year 2019 was the most recent and consistent in terms of data.

The data was provided by two airlines into three categories: Origin, Destination, and Total Fuel Tankering used, and one airline provided just the total amount of Fuel Tankering performed in 2019. The scope of the observation has been to filter only domestic flights inside Brazilian territory, and has not been focused on other country's particularities. In order to preserve the details and specificities of each airline, the data was analyzed and only the total amount of Fuel Tankering used in 2019 was considered.

Based on the data of the total Fuel Tankering quantity, it was calculated the total of CO₂ emitted into the atmosphere in 2019. With these values, it has been possible to know how much carbon credits must be purchased to neutralize the emissions caused by the Fuel Tankering practice. The effort has been to turn a yet unavoids practice into a more eco-friendly one.

As a part of this study, the researchers have needed to understand the sustainability of Fuel Tankering in Brazilian scenario (States apply different tax rates, no carbon emission/neutralization regulation, and no Fuel Tankering methodology focus on sustainability).

The group has interviewed Mr. Pedro Scorza, a Brazilian sustainability expert, who supported that the existing methods in which airlines have been currently using for being sustainable, such as investing in renewing the fleet with more fuel-efficient engines, more

efficient approaches, more direct routes, single-engine taxi at departure and arrivals, have been aimed to reduce the fuel consumption.

However, the Fuel Tankering practices have been still part of airline's plans, efforts and investments in the opposite direction of sustainability and carbon emission neutralization, without considering part of the Fuel Tankering savings to finance the carbon neutralization.

Experimental Design

Data collection was carried out directly in cooperation with the airlines which have strict control of the amount of Fuel Tankering carried out per route. This control has allowed airlines to understand which would be the most profitable routes and to plan a more economical network.

The experimental design was divided into three parts to calculate the amount of carbon that must be purchased to neutralize the emissions.

Part One – Amount of Burnt Fuel

The term “Cost of Weight” was presented at this moment. It represented the extra expenses caused by the addition of weight. In this case, it has been the extra weight from the fuel to the aircraft's initial weight. This calculation was needed to understand what the extra consumption represented in terms of extra CO₂ emissions that was covered in Part Two.

$$T = (F \cdot 4,5\%) \cdot T(\text{AVG})$$

Where:

T = Total fuel consumed

F = Total fuel supplied for Fuel Tanking

T(AVG) = Flight time

For calculation purposes, the value of 4.5% of “Cost of Weight” was used for all stages. This was based on an average between 4% to 5% mentioned for all airlines in the study (Boeing, 2016).

In order to define the flight time of each route, the average time of authorized HOTRANs for each airline was used. “HOTRAN” is the document approved and issued by ANAC and it has formalized the grants for the operation of regular international and domestic passenger and/or cargo airlines as well as the postal network services. The focus here has been the airlines with the respective schedules, flight numbers, frequencies, aircraft types and seat availability (ANAC, 2021).

Part Two – Amount of Carbon Emitted

The calculation of how much carbon has been emitted is a crucial part of this study. This value was the result of the conversion from the extra fuel consumed to the amount of CO₂ this consumption represented. Then, the study has presented the amount of carbon credits to be invested and purchased to neutralize the emissions.

The purchase of carbon credits has served to prove that Fuel Tankering practice can keep helping the airlines by being an efficient economic measure to overcome high local taxes, being sustainable to the environment, and saving an important and expensive input, which is fuel.

After the total value of how much fuel was burnt, the computation of how much carbon was emitted by the airlines part of research project is presented in the formula as follows:

$$CO_2 = \sum M_f * FCF_f$$

Where:

C = CO₂ Emissions (in tons);

M_f = Mass of fuel used (in tons);

FCF_f = Fuel conversion factor of given fuel_f, equal 3.16 (in kg CO₂/kg fuel) for Jet-A fuel / Jet -A1 fuel.

According to ICAO's study (2018), the value of 3.16 was used as a constant when calculating the amount of CO₂ emitted by each passenger. This number has determined the relationship between a ton (1000 kg) of CO₂ emission by a ton (1000 kg) of fuel consumed. The same value was used for the calculation presented in this study.

Part Three – Neutralizing Carbon Emission in Carbon Credits

After knowing how much CO₂ was emitted, there has been calculated how much carbon credit the airline must buy in order to neutralize the emissions arising from Fuel Tankering practice.

The practice of carbon offset trading can be found in two ways: regulatory market and voluntary market. The carbon offsets have been sold in the regulatory market where they have been used as part of a compliance scheme, such as a cap-and-trade system (Kollmuss et al, 2008).

On the other hand, offsets traded on the voluntary carbon market have not been currently part of an existing federal regulatory or compliance scheme (Taylor, 2009).

Considering carbon credit as an asset, the value has varied according to the company that markets it. To perform the calculations, it has been used a company called "MOSS", the world's largest carbon offset platform and the first to tokenize negotiable carbon credits, with the aim of offsetting the bitcoin market's greenhouse gas emissions since its founding in 2013 (Global Warming Focus, 2021).

Carbon neutralization has worked as follows: the airline has produced tons of carbon in its activities. Hence, to zero its emissions, it must buy carbon credits (one carbon credit means one ton of carbon equivalent – CO₂). Thus, a search has been carried out for reliable and certified companies. An example of this would be a company that has captured biogas from a landfill and has transformed it into energy, or even another company that has preserved native forests. These companies have generated carbon credits for the use of clean energy.

These credits have been calculated by the total CO₂ no longer generated. Then a partnership has been created between the companies – one buys the carbon credits neutralizing its emissions and the other receives the investments (eCycle, 2019).

To find out how much carbon credit needs to be purchased, the formula used was:

$$V_c = CO_2 * C_v$$

Where:

V_c = Total amount in USD spent on the purchase of credits

CO_2 = Total amount of CO₂ Emissions amount (in tonnes)

C_v = Carbon Credit Value

After following the three steps mentioned above, it has been possible to prove the negative impacts from Fuel Tankering practice and quantify them. The research group has analyzed more than 90% of the domestic market and exhibited it in total value that the three airlines together should compensate.

Based on the results, each airline may verify and compare their own earnings from the year 2019. The research group could not reach the savings from the airlines since the data was confidential.

The calculations and results are presented in Chapter Four.

Chapter IV

Conclusions

This chapter has described the research's four main conclusion points including subtopics which have described the literature analysis, data gathering methods and results related to neutralization of Fuel Tankering emissions for environmental sustainability.

Brazil has been committed to reducing greenhouse gas emissions in 37% by 2025 and 43% in 2030 using 2005 as the reference. It has been working continuously to meet its challenging greenhouse gas emission reduction targets and had positive results. The magnitude of these targets has exceeded even those of many developed countries (Government of Brazil, 2021).

In this context, the research has raised significant findings that can support the implementation of some actions and has become a way to understand and clarify the Fuel Tankering and carbon emissions theme in the Brazilian aviation scenario.

All the conclusion points were completed through data provided by the three main Brazilian airlines and for confidentiality reasons these data were not stratified by airline, but as a single data with the objective of demonstrating the general conclusions of the research.

The four main conclusion points have been: financial investments to neutralize the carbon emission from Fuel Tankering practice, the difference between States ICMS taxation as one of the root causes of Fuel Tankering existence, the Fuel Tankering environmental consequences have not been part of the airlines account savings, and the carbon emission compensation/neutralization policies have not been detailed and clear in the Brazilian aviation market.

- **Conclusion 1: Financial investments to neutralize the carbon emission from Fuel Tankering practice**

- **Data Gathering**

Data collected from the three largest airlines in Brazil. The total number has represented the amount of extra fuel during 2019 as part of the Fuel Tankering practice.

- **Results**

The total amount of extra fuel was converted into extra emissions caused by extra weight and the amount of carbon dioxide that this has represented. Scenarios were created for the airlines to understand a range of current values to neutralize those extra emissions by purchasing carbon credits.

- **Conclusion**

The environmental impact of the Fuel Tankering practice has not been considered by the airlines. The research group has provided scenarios that each Brazilian airline could apply to its own operation in order to start balancing their savings by neutralizing the negative impacts.

- **Conclusion 2: The difference between ICMS taxation as one of the root causes of Fuel Tankering existence**

- **Data Gathering – Literature Analysis**

According to Brazilian taxation policy, the difference in ICMS State taxes has affected the final customers by increasing the product, services prices, and aviation fuel.

- **Results**

Although real aviation fuel values have been confidential, price differences exist. This results in the effort by the airlines to study and plan to use the Fuel Tankering practice to be as efficient as possible.

- **Conclusion**

Even with negotiation with States for lower taxes, the main reason for the enormous amount of Fuel Tankering practice around every year is the difference in ICMS State taxes values. There have been a few other minor reasons but with a smaller influence on the total quantity.

- **Conclusion 3: The Fuel Tankering environmental consequences have not been part of the airlines account savings**

- **Data Gathering – Literature Analysis**

To calculate the economic and environmental impact of Fuel Tankering practice, simulations have been performed with the EUROCONTROL BADA (Base of Aircraft Data) models based on typical types of aircraft flying in ECAC airspace, considering the distribution of ECAC flights per distance flown and the fuel prices negotiated by two major European airlines.

- **Results**

Considering the example used on this hypothesis, Fuel Tankering would represent 136kg of additional fuel burned per flight (costing €75), generating 428kg of additional CO₂ (i.e., €9 in CO₂ licenses purchased). However, despite the additional cost, Fuel Tankering would still result in net savings of €126 per ton of average flight (Eurocontrol, 2019).

- **Conclusion**

Despite the savings generated by the Fuel Tankering practice, the airlines studied did not take into consideration the environmental impact, and therefore did not account for the purchase of CO₂ to neutralize the extra emissions generated by the practice.

- **Conclusion 4: Carbon emission compensation/neutralization policies have not been detailed and cleared in the Brazilian aviation market**

- **Data Gathering – Literature Analysis**

From the standpoint of this research, there have been articles regarding carbon emissions compensations/neutralizations policies around the world, especially in Europe. However, a few studies have concerned about Brazilian scenario.

- **Results**

Although emission compensation would have three stages of implementation (two voluntary ones from 2021 to 2023, and 2024 to 2026), and a compulsory one between 2027 and

2035, Brazilian iNDC has determined emission reduction goals of 37% by 2025 and 43% by 2030, based on 2005 levels (ABEAR, 2021).

CORSIA may encourage the expansion of offset projects, changing local political dynamics and resulting in different environmental impacts (Gonçalves, 2019).

In Brazil, despite the market's potential, official initiatives to regulate the carbon market have moved slowly (Fontana, 2021).

- **Conclusion**

In the Brazilian aviation market, there has been no specific implementation policy related to the neutralization of Fuel Tankering emissions for environmental sustainability making each airline to take initiatives to adapt itself to the best practices already used in Europe, for example.

Even with CORSIA's influence on the Brazilian aviation market, the focus of aid and support for airlines has been directed to the practice of Fuel Tankering with the objective of providing financial savings without considering the carbon emission compensation/neutralization.

Other factors that could compromise structured actions have been the lack of standardized policies.

Conclusion Details

- **Conclusion 1: Financial investments to neutralize the carbon emission from Fuel Tankering practice**

The data from the three largest airlines in Brazil were gathered by interviewing the teams responsible for the Fuel Controlling. For confidentiality reasons, Table 1 shows the total Fuel

Tankering in kilograms used by all three airlines combined in 2019. This amount has represented an extra fuel burned, which can be translated into 1.074.417 carbon credits required to neutralize the 2019 Fuel Tankering practice in Brazilian aviation industry. The economic savings of the airlines were not part of this study's scope as fuel prices have been confidential and part of the airlines' business strategy.

Total Fuel Tankering (Kg)	Extra Total fuel burned (Kg)	Carbon Credits Required
377.783.583	34.000.522	1.074.417

Table 1 – Total Fuel Tankering, Total extra fuel burned, and the total carbon credits

The total amount spent to neutralize can vary according to the carbon credit quotation. The company used in the study as a reference was MOSS. Their quotation can vary from \$7 to \$20, depending on the amount purchased. It is important to explain that the research group has used data of Fuel Tankering from the year 2019 because it was the most recent year that was not affected by any global externality. On the other hand, the carbon credit quotation has represented the most recent prices from 2021. That was because the study intended to show the required investments to the future using most recent carbon credit price values.

The research group has created three scenarios. Each scenario has presented a simulation of different quantities of Fuel Tankering carried by an airline for one year. The respective carbon credit required for neutralization of the emission was shown as well as, for each case, a minimum, median, and maximum values of \$7, \$13, and \$20 were presented according to Table 2.

Scenario 1: Airline A using 200.000.000 kg of Total Fuel Tankering

Scenario 2: Airline B using 100.000.000 kg of Total Fuel Tankering

Scenario 3: Airline C using 50.000.000 kg of Total Fuel Tankering

Expenses with the purchase of Carbon Credit			
Total Fuel Tankering (Kg)	\$ 7,00	\$ 13,00	\$ 20,00
377.783.583	\$ 7.520.919,00	\$ 13.967.421,00	\$ 21.488.340,00
200.000.000	\$ 3.981.600,00	\$ 7.394.400,00	\$ 11.376.000,00
100.000.000	\$ 2.986.200,00	\$ 5.545.800,00	\$ 8.532.000,00
50.000.000	\$ 995.400,00	\$ 1.848.600,00	\$ 2.844.000,00

Table 2 – Expenses with purchase of carbon credit for scenarios 1, 2 and 3.

See Recommendation 1.

- **Conclusion 2: The difference between ICMS taxation as one of the root causes of Fuel Tankering existence**

According to Brazilian taxation policy, the ICMS taxation has been a State value-added tax (VAT) that affects the final consumer of the products by increasing the final price considering the circulation process (PWC, 2021). The ICMS has varied considerably, from 7% to 35%, and depends on several factors such as the State from which the product has issued, the State to where it would be received as well as how essential the product would be (Jornal Contabil, 2020).

The following table has shown the standard tax percentage rule according to each state of origin according to the state of destination for most products and services.

ORIGEM	DESTINO																											
	AC	AL	AM	AP	BA	CE	DF	ES	GO	MA	MT	MS	MG	PA	PB	PR	PE	PI	RN	RS	RJ	RO	RR	SC	SP	SE	TO	IM
AC	17	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
AL	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
AM	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
AP	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
BA	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
CE	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
DE	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
ES	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
GO	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
MA	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
MT	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
MS	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
MG	7	7	7	7	7	7	7	7	7	7	7	7	18	7	7	12	7	7	12	7	7	12	7	7	12	7	7	4
PA	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
PB	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
PR	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	18	7	7	12	7	7	12	7	7	12	7	7	4
PE	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
PI	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
RN	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
RS	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	4
RJ	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	4
RO	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
RR	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
SC	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	4
SP	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	4
SE	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
TO	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	4
IM	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

* RJ: 20% + 2% DE FECP / *AL: 17% + 1% DE FECP

Table 3 – ICMS tax: origin State vs destination State

The aviation fuel, on the other hand, has not depended only on the previous table. The values have been constantly changing and being negotiated by the parties involved. In the year of 2019, the tax burden applied to the fuel for the commercial aviation business in the north States of Brazil was around 3%, and 7% for other States. The State of São Paulo applied 10% for the fuel specifically to the airlines (Confaz, 2019).

Also, this value can fluctuate according to the negotiations by each airline with a particular State. In summary, it is a complex and important tax that has not been standardized.

The airlines may have good negotiations for an interesting final tax value in a particular State but not in others. This leads to the need of the application of the Fuel Tankering by the aviation industry, which has been focused on economic savings and efficiency resulting in refueling the aircraft much more than needed in order to have economic savings with the

difference in prices to avoid refueling in more expensive locations. These economic differences taken to a year of operation would bring significant savings to the airline.

There have also been other factors that affect the fuel prices, such as local taxes, distribution methods, size of the airline fleet and others. Also, airlines have other reasons for performing the Fuel Tankering practice: disruptions, technical problems with refueling at destination, and refueling to avoid delays (Tabernier et al., 2021). However, Fuel Tankering caused by the difference in Brazilian taxation has happened throughout the years and it has not shown any evidence of being extinguished nor the negative impacts being neutralized.

See Recommendation 2.

- **Conclusion 3: The Fuel Tankering environmental consequences have not been part of the airlines account savings**

To demonstrate the impacts of the Fuel Tankering practice, we used a Eurocontrol (Eurocontrol, 2019) study as a reference.

To analyze the economic and environmental impact of Fuel Tankering, simulations were carried out with Eurocontrol BADA (Base of Aircraft Data) models based on typical types of aircraft flying in ECAC airspace, considering the distribution of ECAC flights by distances flown and at fuel prices negotiated by two majors' European airlines.

The payload has been calculated with a load factor of 80.3% and 124 kg/passenger as used in the European Aviation Environmental Report 2019. One month of ECAC traffic data was used in the simulations (June, 2018).

Round trip distance (each leg)	Practice	Fuel consumption (kg)		% extra fuel burnt for A-B trip	Extra fuel burnt for A-B trip (kg)	Extra CO ₂ emitted for A-B trip (kg)	Cost of extra fuel burnt (€) for A-B trip
		A-B Trip	B-A Trip				
300 NM	no tankering	2,037	2,037				
	full tankering	2,082	2,037	2.21%	45.1	142	24.8
600 NM	no tankering	3,592	3,592				
	full tankering	3,760	3,592	4.66%	167.5	528	92.1

Table 4 – Fuel consumption

Table 4 (A-B trip and the return B-A trip) has presented the extra cost and CO₂ by doing Fuel Tankering and its cost, for 300 NM and 600 NM maximum range trips, which have represented respectively to 30% and 50% of all ECAC flights.

As a result, in ECAC, Fuel Tankering would represent 136 kg of additional fuel burnt per flight concerned (costing 75€), generating 428 kg of additional CO₂ (i.e., 9€ in purchased CO₂ allowances). Nevertheless, despite the additional cost, Fuel Tankering would still result in a net saving of 126€ per flight ton average (Eurocontrol, 2019).

Notwithstanding the economic advantages acquired in the Fuel Tankering practice, it was possible to verify that the three airlines studied did not consider the environmental impact generated by this practice, therefore, they did not consider the purchase of CO₂, or any other action, to neutralize the extra emissions generated.

See Recommendation 3.

- **Conclusion 4: Carbon emission compensation/neutralization policies have not been detailed and cleared in the Brazilian aviation market**

The program CORSIA was proposed in 2016 by ICAO as an agreement aimed to neutralize the growth of carbon emissions on international flights, and, according to the agreement, airlines that did not meet the targets would have to buy credits on the carbon market (IKI, 2021).

Emission compensation would have three stages of implementation (two voluntary ones 2021 to 2023 and 2024 to 2026, and a compulsory one between 2027 and 2035). In practice, such an international policy would cause fuel to be charged by the compulsory acquisition of carbon credits.

It has been also necessary to take the Brazilian internal challenges into account. They were defined in the iNDC, signed at the 21st Conference of Parties of the UNFCCC held in December of 2015, in Paris.

These commitments have been even more aggressive than those determined by ICAO and valid for the entire national productive sector, including aviation, since Brazilian iNDC has determined emission reduction goals of 37% by 2025 and 43% by 2030, based on 2005 levels (ABEAR, 2021).

In order to Brazil follow up the global scenario, there has been the implementation of RenovaBio, the National Biofuels Policy, and created decarbonization credits to contribute to Brazil commitments under the Paris Agreement under the UNFCCC.

In the Brazilian aviation market, there has been no specific implementation policy related to the neutralization of Fuel Tankering emissions for environmental sustainability making each airline to take initiatives to adapt itself to the best practices already used in Europe, for example.

CORSIA has been a limited policy because when it transforms the intensive emitters of greenhouse gases into participants in a system, there has been no individual responsiveness, but

rather a general incentive to prioritize actions with better economic cost-benefit. Therefore, offsetting has blurred the cause-consequence link and it has diluted the social and environmental responsibility for emissions.

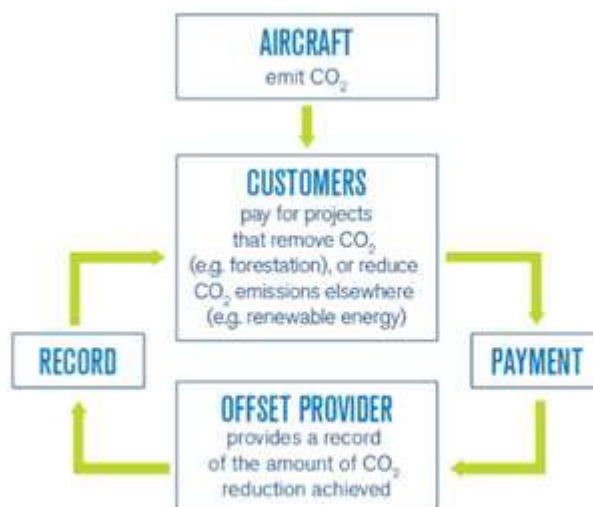
The role of Brazil in CORSIA's negotiations have not incited a stronger agreement in an environmental perspective, which means that the country has not led or pushed to an agreement with more responsibilities and obligations to the parties involved. Brazil, as other countries at the ICAO's negotiation, has defended its airline interests in detriment of a more effective international aviation emissions reduction system. Considering specifically the Brazilian reality, CORSIA may encourage the expansion of offset projects, changing local political dynamics and resulting in different environmental impacts (Gonçalves, 2019).

Even with CORSIA's influence on the Brazilian aviation market, the focus of aid and support for airlines has been directed to the Fuel Tankering practice with the objective of providing financial savings without considering the carbon emission compensation/neutralization.

An action example that have been taken to neutralize carbon emissions, a Brazilian airline, in partnership with MOSS, the largest environmental carbon credit platform in the world, made the first flight in the world to have its carbon footprint fully offset through a Green Token cryptocurrency MCO2. This flight, with destination to Fernando de Noronha Island, has aimed to collaborate with the reduction of 25% of the island emissions, once more than half of total emissions were generated by air transportation in the island (Aviación al Día, 2021).

Moreover, both organizations have joined forces to announce to their customers a pioneering initiative in the Latin America: Anyone who has flown with the airlines would have

the opportunity to offset the greenhouse gas emissions associated with their flight by purchasing carbon credit.



IATA – Aviation Carbon Offsetting Guidelines for Voluntary Programs

According to the World Bank, currently around 60 carbon pricing initiatives have been active or being implemented among countries and sub-national governments worldwide. In Brazil, despite the market’s potential, official initiatives to regulate the carbon market in Brazil have moved slowly (Fontana, 2021).

In addition to individual carbon offsets made by passengers, other actions to be taken would be the development of biofuels, search for efficiency savings in the operations, flight planning and execution of best practices, and constant fleet renewal for more efficient aircraft (MOSS, 2021).

The three Brazilian airlines used as the basis for this research have committed to the “net zero” under the SBTi, and the airlines have up to two years to develop a long-term emissions reduction strategy and submit their plans for approval. Actions such as the purchase of carbon

credit have been presented as a sustainable measure option and possible entry into the plans proposed by the airlines, indeed, the purchasing emission units have been currently more reasonable than other actions, as carbon offset prices have been much lower, and present availability in the market (Capaz et al, 2020).

Other factors that could compromise structured actions have been the lack of standardized policies since government agencies have been waiting airlines to take actions to ensure their long-term position in a sustainable society, while airlines have had the same perception and they have been awaiting regulation, incentives and best practices that would not generate additional costs or compromise competitiveness.

See Recommendation 4.

Chapter V

Recommendations, Future Research, and Lessons Learned

This research project's purpose was to demonstrate the total Fuel Tankering quantity data used by the Brazilian airline industry in 2019, explaining the total carbon emission that was emitted, and appraising the average cost of carbon to neutralize the Fuel Tankering used in the same year by purchasing carbon credits.

Based on the research conclusions, some recommendations become important to support solutions for the adjustment of savings by incorporating the neutralization of carbon emissions.

Finally, it has been possible to state that the Brazilian aviation industry can neutralize the carbon emissions from the Fuel Tankering practice savings sustainably.

- **Recommendation 1**

As shown in the study, the Fuel Tankering practice has been extremely profitable, and our recommendation has been that it can be profitable and sustainable.

- **Recommendation 2**

Although the political aspects have not been the main purpose of this study, the difference in ICMS taxes has made aviation industry less efficient and more polluter. Our recommendation has aimed to levelling of the State taxes in order to reduce the need of the airlines to apply procedures that negatively affect the environment.

- **Recommendation 3**

In order to consider the environmental impact and include financial savings on the Fuel Tankering practice, the Brazilian airlines could consider the purchase of CO2' credits, or any other actions, to neutralize the extra emissions generated by this practice.

- **Recommendation 4**

Implementation of carbon emission compensation/neutralization policies in the Brazilian aviation market using part of the financial savings obtained with the Fuel Tankering practice.

Recommendation Details

- **Recommendation 1:**

To make the practice of Fuel Tankering sustainable, airlines must allocate part of the savings generated to the purchase of carbon credits, where each airline would be able to perform it separately.

To be able to offset the carbon emitted, airlines must first know the total amount of carbon emitted, and with this total they must hire a company that has been sold carbon credit.

These companies have not been fixed a CO2 value (different values according to the amount purchased), so airlines must buy in enormous quantities, and a good strategy would be the purchase once a year calculating the total of Fuel Tankering savings and converting into the purchase. This method could not only be economical as it would be easier to calculate the "expense" for the next year's budget since it would be a crucial part of financial health.

- **Recommendation 2:**

The Fuel Tankering practice may not be extinguished completely. There have been a few satisfactory reasons for carrying more fuel than the minimum required for a safe flight. Most of the reasons refer to the lack of facilities, supply, or specific operational strategies. However, a deliberate and uncontrolled extra emission of pollutants into the atmosphere should not be considered reasonable nowadays.

Each airline has different applications of taxes in different States according to negotiations, and when there has been a slight difference between States taxes, the Fuel Tankering practice has become financially interesting to the airlines but environmentally impactful.

This recommendation focuses on improbable but necessary leveling of ICMS taxes in Brazil. It would bring an important change in how the airlines deal with the environment daily. By reducing part of the extra and avoidable emissions shown in this study, the aviation industry would be more sustainable.

- **Recommendation 3:**

The Brazilian airlines already have an understanding that sustainable measures have been necessary to meet a social appeal for a less carbon polluted world.

From the standpoint of this study, there have been no studies that consider the environmental impacts suffered by the Fuel Tankering practice. Therefore, it has been understandable that airlines have not added the equation of financial savings achieved by the practice of Fuel Tankering for an environmental offset to neutralize the extra carbon emitted.

In an effort to airlines consolidate themselves as green organizations and precursors in sustainable actions, it has been essential that they consider the costs of offset carbon emissions, in the economic savings of the Fuel Tankering practice.

As shown in this research, there have been alternatives for airlines to offset the carbon emitted, bringing financial savings to invest in neutralize the carbon emitted. According to Hagemann (2015), there has been a passenger's willingness to pay more to fly with a green airline influencing the airline choice at the ticket booking.

- **Recommendation 4:**

After the data have been collected and analyzed, and the conclusions presented in the previous chapter, this research has recommended that carbon emission compensation/neutralization policies be implemented in the Brazilian aviation market based on the best practices adopted in the world, meeting the requirements defined by the CORSIA program and using as methodology the programs used by IATA on acquisition of carbon credits since the three main Brazilian airlines are members of this association.

Among specific actions to be implemented, the most important one has included the use of part of the financial savings obtained with the Fuel Tankering practice to fund the carbon emission compensation/neutralization policy developed for the Brazilian aviation industry in an environmentally responsible mindset.

No less important, is it necessary to consider the creation of public policies for the development of biofuels offering exemptions of taxes to encourage their use and the creation of a national program focused on long-term emissions reduction, use of more efficient aircraft through fleet renewal, infrastructure/air traffic management improvements, and a national

program to structure a new carbon credit market, which is still little explored, involving governments, airlines, and society.

Future Research

- Fuel Tankering practiced by the same airlines in a post-pandemic scenario comparing to the findings presented in this research;
- Carbon emission compensation/neutralization policies implemented in the Brazilian aviation market based on the requirements defined by the CORSIA program and/or using the IATA methodology;
- Public policies for the development of biofuels and the Brazilian carbon credit market;
- Possible leveling the ICMS in Brazil and its impacts in the Fuel Tankering practice;
- Comparison between sustainability and emissions neutralization policies through carbon credits of the three Brazilian airlines used in this study.

Lessons Learned

- The research group could gather confidential data from the three main Brazilian airlines, which have been responsible for the biggest market share. This achievement was important for allowing this study to be consistent;
- This study was complex in terms of data gathering as it has approached a sensitive and confidential subject to the airlines directly affecting their competitiveness in the market;

- The study has presented that the investments required for the neutralization of Fuel Tankering emissions for environmental sustainability is relatively low when compared to the savings provided by the Fuel Tankering practice, so it has been possible to improve financial savings with small investment in sustainability;
- ICMS has been one of the main factors contributing to the high price and enormous differences in fuel prices between Brazilian States in a different scenario than in Europe or the United States, making the Fuel Tankering practice essential to maintain the airlines' financial margins.

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