In-Flight Fuel Management
Committing to the Destination

Embry-Riddle Aeronautical University
Aviation Management Program – Class of 2020
IN-FLIGHT FUEL MANAGEMENT – COMMITTING TO THE DESTINATION

by

Aldo Bien
Daniel Araguaia Galli Ribas
Paulo Cesar Serafim Pacheco
Rodrigo Garcia de Freitas Cardoso

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Embry-Riddle Aeronautical University
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This Capstone Project was prepared and approved under the direction of the Capstone Project Chair, Dr. Leila Halawi. It was submitted to Embry-Riddle Aeronautical University in partial fulfillment of the requirements for the Aviation Management Certificate Program.

Capstone Project Committee:

___________________________________________
Dr. Leila Halawi
Capstone Project Chair

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Abstract

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This project intends to clarify the Brazilian Civil Aviation Regulation RBAC 121 on its topic relating to the current ICAO recommendation from Doc. 9976 (Flight Planning and Fuel Management Manual), which regards the committing to the destination policy.

The present Brazilian regulation is not precise whether the alternate fuel could or could not be used to proceed to the original destination without compromising the emergency fuel, once exact specific requirements are met. As a result of unclear directrices, each major airline in Brazil comprehends and applies the ICAO recommendation in its way. Such a non-standardized interpretation of the current regulation certainly compromises both the airline industry's safety and efficiency in the country. Therefore, this project proposes a more comprehensive and clear text for the Brazilian rules, encouraging airlines to adhere to what the ICAO recommendation preconizes widely.

To meet this goal, the project takes advantage of statistics regarding diversions and fuel planning from two major airlines in Brazil, data from the National Aeronautical
Accidents Investigation and Prevention Board (CENIPA) concerning fuel emergencies, and a sample of airport numbers referring to runway closure unforeseen events. A survey among Brazilian airline pilots regarding their understanding of this subject and the airlines' estimated costs for diverting to alternate airports have also been utilized. These data, alongside cited well-experimented practices adopted on this matter worldwide, reinforce the operational and financial benefits of uniformly and broadly adopting the ICAO recommended policy.
Este projeto tem por intuito clarificar o conteúdo do Regulamento Brasileiro de Aviação Civil RBAC 121 em seu tópico relativo à presente recomendação da International Civil Aviation Organization (ICAO) extraída do Doc. 9976 (Flight Planning and Fuel Management Manual), no que se refere à política operacional conhecida como committing to the destination.

A atual regulamentação brasileira não é precisa no que se refere ao combustível de voo para o aeroporto de alternativa poder ou não ser utilizado no prosseguimento para o aeroporto original de destino sem que se comprometa o combustível de emergência, uma vez que condições específicas exatas sejam cumpridas. Como resultado de diretrizes não-objetivas, cada uma das grandes empresas aéreas brasileiras compreende e aplica a recomendação da ICAO à sua própria maneira. Essa interpretação não padronizada da regulamentação atual certamente compromete tanto a segurança quanto a eficiência da indústria da linha aérea no país. Portanto, este projeto propõe um texto mais abrangente e
claro para as regras brasileiras, encorajando as empresas aéreas a aderirem amplamente ao que a recomendação da ICAO preconiza.

Para atingir esse objetivo, o projeto se vale de estatísticas com relação a voos alternados e planejamento de combustível de duas das maiores companhias aéreas do Brasil, dados do Centro de Investigação e Prevenção de Acidentes Aeronáuticos (CENIPA) sobre emergências relacionadas a combustível, e uma amostra dos números de aeroportos referentes a eventos não previstos de fechamento de pistas. Também foram utilizados uma pesquisa entre pilotos de linha aérea brasileiros com relação a sua compreensão sobre o assunto e o custo estimado das companhias gerado por voos alternados. Estes dados, juntamente com as já largamente experimentadas práticas nesse sentido em âmbito mundial, reforçam os benefícios operacionais e financeiros da adoção ampla e uniforme da política recomendada pela ICAO.
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Chapter I
Introduction

Since the first half of the twentieth century, a period in which aircraft evolution took place quickly and robustly, aviation has changed concerning the guidelines, rules, and laws that regulate air activity (ICAO, 2020). Over time, these changes aim to maintain the flight operations in the highest safety standards, profoundly contributing to this activity's efficient development. The policy of minimum fuel required could not be different. Several fuel regulations have already been created to meet airline operators’ needs worldwide (Tang, Wu & Tan, 2020). Norms seek the industry's high safety standard, concomitantly allowing airlines to enable profitable operations regarding passengers and cargo transport in the domestic and international network.

In the second half of the last century, regulatory changes over time allowed competition between airlines, as many of them had previously operated in government-regulated markets (ITF, 2019). This competition started to happen in an industry with high fixed and variable costs and reduced profit margins (Vasigh, Fleming & Tacker, 2018). This new aviation era has further intensified the search for cost optimization, especially concerning fuel efficiency, one of the main cost vectors for this industry worldwide, which is even a more comprehensive touchy point for any Brazilian airline (ANAC, 2019).
The great dilemma then became the proper fuel quantity to be supplied to execute a given flight, since providing less than necessary fuel impacts the flight safety directly. Also, filling more than what would be straightly essential to fly that sector safely would negatively affect the airline's cost, as fuel burn is directly related to the plane's weight. The heavier it is, the higher the use. On average, an aircraft will burn around 0.025kg up to 0.045kg of fuel for each kilogram carried per hour, which stands for 2.5% up to 4.5% of the extra weight (ICAO, 2014). Equalizing the Risk and Cost balance concerning fuel has been challenging for regulatory agencies worldwide and all airlines.

The development of modern aircraft and the entire industry's infrastructure allowed a significant improvement in several systems' accuracy and reliability, such as the flight management system. Nowadays, the systems are integrated with other company tools, like computerized flight planning, enabling better data analysis and increasing the amount of information available for the airline (Altus, 2009). Therefore, better fuel
monitoring became possible, along with a more reliable and accurate consumption forecast throughout the flight (ICAO, 2015). Moreover, there has been an evolution in airlines' risk management processes in the last decades through data collected by tools such as Flight Data Monitoring (FDM). This system uses real data obtained all over the flight for various purposes, including feeding the risk management matrix with reliable information (EAFM, 2017).

In the wake of this cadenced technological evolution, ICAO released a publication to update some guidelines that emphasized the importance of fuel planning and in-flight fuel management, the Doc 9976, also known as Flight Planning and Fuel Management Manual. This manual encompasses the committing to the destination policy, among other topics, an in-flight fuel management decision that targets the increase of flight safety levels and efficiency standards. It offers pilots more flexibility to go through their decision-making process concerning the landing airport. Simultaneously, it reduces airline costs, as it avoids unnecessary diverted flights (ICAO, 2015).

**Project Definition**

This project aims to: (a) collect data, through an online survey, to demonstrate that the concept of in-flight fuel management, also known as committing to the destination (which means using part of the alternative fuel originally planned to land at the destination), is not widely used by Brazilian pilots; (b) demonstrate through that same research that the Brazilian regulation (RBAC 121), in its chapter 121.648 (in-flight fuel management) is not precise about the possibility of committing to the destination, as recommended by ICAO, and already contained in several regulations from different
nations, such as all European Union countries (EASA, 2019), and the United Arab Emirates (GCAA, 2020); (c) demonstrate the advantages of having a clear and comprehensive committing to the destination policy concerning flight safety, as well as the reduction in airline costs.

**Project Goals and Scope**

This project aims at thoroughly demonstrating that the committing to the destination policy recommended by ICAO works as an additional tool for pilots in terms of in-flight fuel management. The re-analysis during the flight allows the pilot-in-command (PIC) to convert the fuel initially planned for diverting into fuel to continue to the destination. That procedure could only be accomplished once regulatory-defined conditions (such as the meteorology and a reliable expected approach time) were reached to ensure the aircraft would land with the usable fuel equal or higher than the final reserve fuel (ICAO, 2015).

Therefore, this project intends to prove a gap in the Brazilian regulation regarding the alternate fuel use to allow the landing at the destination airport through research carried out with airline pilots. Moreover, the work shall expose the fact the Brazilian aeronautical community is not adequately making use of this valuable option.

Nonetheless, modifying this aspect of the current regulation would allow an additional possibility for pilots to decide the best course of action after a careful analysis of the conditions for both the destination and alternate airports, as well as the remaining fuel on board, in a given scenario. Thus, this work intends to directly contribute to
improving flight safety, minimizing the risk of an emergency fuel situation, and reducing airlines' costs regarding diverted flights.

**Definitions of Terms**

Alternate fuel  
The amount of fuel required to allow the execution of a missed approach at the destination airport, climb to the cruise altitude, fly on the route to the alternative airport, descend to the initial approach fix, and perform the approach land at the alternate airport (ANAC, 2020, RBAC 121.645 (c) (4)).

Emergency Fuel  
When the amount of usable fuel that would be available when landing at the nearest aerodrome where a safe landing can be made is less than the amount of planned final reserve fuel (ANAC, 2020, RBAC 121.648 (b) (3)).

Final Reserve Fuel  
For airplanes with a turbine engine, the amount of fuel required to fly for 30 minutes at holding speed, 1,500 feet over the elevation of the aerodrome under the ISA atmosphere (ANAC, 2020, RBAC 121.645 (c) (5) (ii)).
### List of Acronyms

<table>
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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANAC</td>
<td>Agência Nacional de Aviação Civil</td>
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<tr>
<td>APU</td>
<td>Auxiliary Power Unit</td>
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<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<td>ATS</td>
<td>Air Traffic Services</td>
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<tr>
<td>CAA</td>
<td>Civil Aviation Authority</td>
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<tr>
<td>CENIPA</td>
<td>Centro Nacional de Investigação e Prevenção de Acidentes Aeronáuticos</td>
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<tr>
<td>DECEA</td>
<td>Departamento de Controle do Espaço Aéreo</td>
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<tr>
<td>EASA</td>
<td>European Union Aviation Safety Agency</td>
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<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
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<tr>
<td>FOQA</td>
<td>Flight Operational Quality Assurance</td>
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<tr>
<td>FOO</td>
<td>Flight Operational Officer</td>
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<tr>
<td>GCAA</td>
<td>General Civil Aviation Authority – United Arab Emirates</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<tr>
<td>ISA</td>
<td>International Standard Atmosphere</td>
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<td>MFOD</td>
<td>Minimum Fuel Over Destination</td>
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<td>OCC</td>
<td>Operations Control Center</td>
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<tr>
<td>PIC</td>
<td>Pilot-in-Command</td>
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<tr>
<td>RBAC</td>
<td>Regulamentos Brasileiros de Aviação Civil</td>
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Chapter II
Review of the Relevant Literature

Background

The aeronautics industry has undergone several changes over time, most commonly due to compliance with standards that assure constant improvement for flight safety and efficiency levels. One of the relevant aspects contributing to the system's overall safety goal concerns the fuel calculation policy during the flight planning phase.

At the end of the forties, regulations emerged to define rules concerning fuel planning policies for civil aviation. However, these were times when highly developed technologies were not part of people's daily life, let alone a dawning industry. The aviation system network was then dealing with unreliable meteorological reports, shallow support from flight dispatch teams to assist with flight planning, precarious and scarce air navigation aids, and unreliable aircraft instruments. Altogether, these conditions affected precise predictions for fuel consumption. Understandably, that scenario used to end up in excessive fuel loading, as necessary to ensure the required operational safety level (ICAO, 2015).

The advancement of technology has brought the aeronautical market more predictability and accuracy regarding flight planning variables. That was made possible through the fast-paced development of tools and resources such as the computerized flight plan, precise weather forecast and fuel consumption calculations, and more efficient flight routes via the multiplication of navigation aids. This industry's evolution allowed airlines to continuously re-analyze the operational processes by using updated
information through state-of-the-art equipment, both in the flight planning and in-flight phases (ICAO, 2015).

Since the 1980s, the airline industry has experienced an extremely competitive environment among its players in most domestic and international markets. This present reality stimulates an acuter search for operational improvement, which means being operationally efficient and promoting, at the same time, flight safety to higher standards. The reduction in operating costs became a common issue for all companies. Their betterment on this matter is directly linked to the evolution and optimization of the flight planning phase (Singh & Sharma, 2015).

The fuel burn reduction also contributes positively to the environment, reducing harmful gas emissions, such as carbon dioxide and carbon monoxide (Li, Yang, Liu, Yu, Tian, Zhou, Zhang & Wang, 2018). The commonly called "green practices" and their operational actions also positively impact any airline's overall revenue and image (Migdadi, 2018). The concern with natural resources and the planet environment has become an excellent value for many passengers. In this regard, the airline industry alone was responsible for around 2.4% of all global carbon dioxide emissions in 2018 (EESI, 2019). Therefore, it became crucial for regulations and procedures to be aligned with this market demand trend since process-based actions have vital participation in the search for efficiency (Migdaldi, 2018).
**Fuel planning and in-flight fuel management**

The Civil Aviation Authorities (CAA) worldwide are responsible for defining air operations regulations, preferably following ICAO guidelines and recommendations. CAAs need to consider their regions' characteristics and particularities and the airlines they oversee when developing and adopting such standards. Those organs will strive to maintain the best possible practices and balance between their system's flight safety and efficiency.

The regulations regarding flight planning play an essential role in this process. They are usually prepared considering the air traffic management (ATM) capabilities, national weather forecast system, airport infrastructure, and airport availability, among other aspects and traits (ICAO, 2015).

As per the country's continental dimension, Brazil's civil aviation system works as a vital transport mode to leverage its economic-social development. The authority responsible for establishing and supervising aeronautical regulations is the *Agência Nacional de Aviação Civil* (ANAC). Like most similar agencies worldwide, the Brazilian governmental entity is responsible for ensuring the civil aviation players and stakeholders comply with the standards it develops and defines, thus keeping up the security and safety policies and practices with world-class levels.

The operation of airlines is regulated by the *Regulamento Brasileiro de Aviação Civil* (RBAC) 121. Paragraph 121.645 regulates the minimum fuel required for a flight's execution, impacting the companies' flight dispatch department's flight planning phase.
According to this current regulation, every operator, taking into account the weather conditions available, must ensure that a jet plane has sufficient fuel to (ANAC, 2020):

- Taxi the aircraft at the origin airdrome.
  
  Technical term: *Taxi fuel*, considering the characteristics at the airfield of origin, and, if applicable, the amount of fuel concerning the Auxiliary Power Unit (APU) fuel consumption.

- Fly to a destination airdrome.
  
  Technical term: *Trip fuel*, which is the fuel required to fly to the destination airport, what considers enough quantity to take off, climb, operate in a cruise flight level, descent, approach, and land at the destination;

- Fuel for unforeseen situations.
  
  Technical term: *Contingency fuel*, which stands for the amount of fuel equivalent to 5% or 10% of the trip fuel (depending on whether the airline has a fuel consumption monitoring program).

- Fly to an alternative airdrome.
  
  Technical term: *Alternate fuel*, which is equal to the amount of fuel required to perform a missed approach, climb, fly on the cruise flight level, descent, carry out an approach procedure, and land at the alternative airfield.

- Fuel to carry out a holding procedure over the alternate airport.
  
  Technical term: *Final reserve fuel*. It must be equal to the amount of fuel required to fly for 30 minutes at 1,500 feet, near the alternative airport at holding speed, ISA conditions.
- Additional fuel uplifted to cover dispatched technical issues.

  Technical term: *Additional fuel*. Fuel added to comply with a specific regulatory or company requirement.

- Extra fuel uplifted due to pilot or flight dispatcher discretion.

  Technical term: *Extra fuel*. The optional amount of fuel above the minimum fuel required by this regulation, defined by flight dispatcher or captain discretion.

For a better understanding of the rules regarding the minimum fuel required, Figure 2 below shows each quantity of fuel needed by the regulation:

![Figure 2 – Minimum fuel required by RBAC 121.](image)

Fuel represents one of the highest operational costs. Therefore, airlines understandably seek to reduce this expense as much as possible. However, this cost depends on two factors, only: the fuel price and its operational efficiency (Ayra, Insua and Cano, 2014). As the kerosene (jet fuel) market value is beyond the airlines' control, it
remains for the companies to develop policies and procedures to optimize this resource, thus improving their efficiency. Therefore, fuel planning and in-flight fuel management have gained paramount importance in the last decades since optimization and efficiency necessarily develop through these two phases (ICAO, 2015).

Fuel planning optimization is currently enabled through modern tools and software. Flight dispatchers have access to real-time data. The available information allows for more economical flight levels and optimizes the alternative airport choice (depending on the weather, airline's local infrastructure, and overall costs). State-of-the-art technologies facilitate determining the optimum speed and even defining the amount of fuel for holding closer to the destination to avoid an undesired time and money-consuming diversion.

All these tools increase safety margins and efficiency, decreasing the fuel quantity needed for that given flight, which also results in reducing the aircraft fuel consumption (ICAO, 2015). It is worth highlighting that the lack of predictability and updated data would cause a more considerable amount of fuel to be carried than necessary, increasing the operational costs (Hao, Hansen & Ryerson, 2016).

In 2015, ICAO published the Doc 9976 Flight Planning and Fuel Management (FPFM) Manual, stressing the importance and the interdependence between planning and in-flight phases regarding fuel efficiency.

Following ICAO recommendations and guidelines, some aeronautical authorities have adopted procedures in their regulations that allow airlines to operate more efficiently (EASA, 2016 & GCAA, 2020), seeking to raise the already high safety levels experienced by the industry. ICAO stresses that in-flight fuel management policies do not
replace those for fuel planning; however, they guarantee that the planning phase's considerations are continually validated. This continuous evaluation and re-analysis ensure that the flight is carried out within the required safety standards with maximum efficiency. Figure 3 shows the pre-flight process until the safe landing, making evident the interdependence between the planning and the in-flight phase (ICAO, 2015).

![Diagram](image)

**Figure 3 – Fostering a culture that ensures safety standards from the planning phase until the landing.**

During the flight execution, the flight crew is responsible for monitoring the systems and checking fuel consumption versus fuel planned by the flight dispatcher. Any difference between the expected and the actual fuel burned can impact the operation. As ICAO Annex 6 makes clear, the pilots' in-flight fuel management must guarantee the safe completion of the trip. For that purpose, some deviations from the initial planning might be necessary, such as divergent routings, weather, mechanical failures management, and different speeds due to ATC requests (Dorneich, Whitlow, Miller, & Allen, 2002). Reconciliation between the actual performance and the flight dispatcher planning is vital.
to the in-flight fuel management success, and it must be done on an ongoing basis (ICAO, 2015).

Among other duties, the pilot-in-command (PIC) must monitor the amount of fuel remaining on board and ensure that a safe landing can be made with final reserve fuel in the tanks. (ANAC, 2020). Many factors can contribute to the real fuel consumption being higher than the planned fuel burn, such as (ICAO, 2015):

- Longest authorized route.
- Less economic flight levels.
- Aircraft heavier than the planned weight.
- Different winds, with a higher headwind component than forecasted.
- More extended taxis at the airport of origin.
- Speeds required by traffic control are less economical than planned.
- Extra holding time due to ATC flow control.

The flight crew needs to have the flexibility and understand the respective regulations to perform adequate in-flight fuel management. It will be the pilots’ call to make the necessary decisions to arrive at the destination, complying with the legal requirements from doors closing on.

In general, the aircraft initiates an approach procedure for landing at the destination with fewer available options than when it took off. Regardless of the flight time and operational peculiarities, the amount of fuel in the tanks during the descent phase is very similar for airliners, as shown in figure 4:
Figure 4 – Expected fuel onboard close to the destination.

At this point in the flight, pilots need as many options as possible to manage any unforeseen situation. Depending on the amount of fuel onboard and some factors, such as weather and air traffic, the crew might alternate. However, the option for proceeding to an alternative airport is usually the last resource in the flight crew’s decision-making process. In addition to the impaired punctuality aspect, diversions produce many costs for the airlines, as shown below (Ayra, Insua & Cano, 2014):

- Additional Air Traffic Services (ATS) charges.
- Fuel costs.
- Maintenance costs.
- Handling costs.
- Crew costs.
- Other costs, including passenger costs (meal, hotel, transportation, among others).
Concerning all those potential efficiency setbacks mentioned above, ICAO developed and recommended a procedure that gives pilots more options to accomplish their in-flight fuel management in the original destination's vicinity. This policy is called "committing to the destination." It allows the captain to convert the fuel initially planned by the flight dispatcher as an alternate fuel to land at the destination airport. Rather than diverting to the alternate airfield, this practice allows the captain to "diverting or committing" to the flight's original destination. In other words, subject to assessing reasonable certainty of landing, it makes alternate fuel available to proceed to the destination. Some circumstances must be present in the given scenario so that the PIC can commit to the destination, such as (ICAO, 2015):

- An assured landing in the prevailing and immediate forecast conditions (including likely single equipment failures).
- An expected approach time or confirmation from ATC of maximum likely delay.
- Landing must be done with the amount of fuel planned as final reserve fuel in the tanks.

The committing to the destination policy recognizes that the crew's assessment of meteorology and traffic over the destination is considerably more reliable and accurate than the same evaluation concerning an alternative airport. Sometimes, it is necessary to fly for one hour to the alternate airport. The aircraft arrives with the amount of fuel very close to the final reserve fuel (equivalent to 30 minutes of flight endurance), without much margin to carry out a holding procedure at the alternative airport. Moreover, the
detouring flight time affects the predictability of weather conditions and the alternative local air traffic situation that should have been considered before diverting. Not to mention the risk of unforeseen events, such as the possibility of a bird strike experienced by another aircraft a few minutes before landing, which usually suspends the runway operation for 5 to 15 minutes (due to the need for a runway assessment). There could also be an airport electrical power shortage, an airport bomb threat, an aircraft failure blocking the runway, or any other issue driving the airport operations to become impracticable.

The more fuel the aircraft has at that decision point, the more waiting time the flight crew will have to deal with the disruptive situation (Drees, Mueller, Schmidt-Moll, Gontar, Zwirglmaier, Wang, Straub, 2017). The PIC will then have the prerogative decide whether to divert or remain on hold close to the original destination, ensuring landing with no less than the final reserve fuel.

It is crucial to highlight that most diversion decisions, regardless of the "divert to the alternative" or "commit to the destination" strategy adopted, mean that the aircraft will land without a further alternate airport available considering its remaining fuel. This fact makes this decision not unique (ICAO, 2015).

*European regulation*

The United States and Europe have the two most robust aviation operational environments in the world. Although both have reliable systems, some features distinguish one from the other. Europe has a fragmented Air Traffic System composed of approximately 40 Air Navigation Services Providers, making collaborative decision making difficult (ICAO, 2015). Besides, the exchange of information between ATC
Centers and airlines is restricted, limiting the companies' flight dispatching and Operational Control Centre (OCC) departments' proactive performance. When it comes to the United States system, there is a constant action by the flight dispatchers that focus on assisting pilots by providing relevant flight information and participating in in-flight management. The regulation responsible for American companies' operation - Code of Federal Regulations (CFR) Title 14, Chapter I, Part 121 - makes the flight dispatcher accountable for complying with established standards (FAA, 2020). In Europe, as in Brazil, in-flight fuel management and diversions are almost the captain's responsibility solely. This operational characteristic shared between the Brazilian and European systems makes airlines, through their pilots, more reactive rather than predictive or proactive in the decision-making process (ICAO, 2015).

Comming the destination policy is already adopted by European regulation. The PIC bears the responsibility and authority to decide, in compliance with legal provisions, whether to proceed to the alternative or to use the alternate fuel to land at the destination.

As Figure 5 makes clear, if the crew foresees a landing at the destination airport with the fuel quantity lower than the amount required for diverting added to the final reserve fuel, the decision to proceed to the destination or continue to the alternate airdrome is up to the commander. Besides, he/she must always make a careful analysis concerning destination and alternate airdromes conditions to assure that the landing occurs with the final reserve fuel in the tanks, according to the European Union regulation N° 965/2012, CAT.OP.MPA.280 – In-flight fuel management – aeroplanes (b)(2)(i) (EASA, 2019), presented in figure 5 below:
The concept of committing to the destination is widely used by European airlines (ECA, 2017), and operators showcase good numbers regarding safety events related to fuel management. Among 40 safety issues analyzed by the Safety Intelligence and Performance Department of EASA, referring to 2019 data (EASA, 2020), fuel management events are one of the most unusual situations, as shown in figure 6 below:
Note: Every occurrence receives an Aggregated European Risk Classification Scheme (ERCS) risk classification. The overall risk level is calculated, defining the risk level and the critical risk area. It ensures that the issue has been correctly specified and evaluated (EASA, 2020).
The few events related to in-flight fuel management in Europe reinforce the central idea defended by ICAO about committing to the destination, providing an additional option for pilots in the decision-making process, thus maintaining the operational safety levels. Besides, it prevents some flights from going to an alternative airport, contributing to the reduction of airlines' costs and the reduction of CO2 emissions into the atmosphere.

**Brazilian regulation**

ANAC, following the ICAO guidelines and through the RBAC 121 regulation, defines the rules and policies applicable to all Brazilian airline companies. It includes the strategies applied by the flight dispatchers regarding fuel planning and the relevant rules concerning in-flight fuel management (ANAC, 2020). Every airline pilot must be aware of this regulation and the impacts it causes on day-to-day operations. The content related to fuel planning, including the rules that establish the minimum fuel required, is widely known in the aeronautical environment. Everyone involved in the operational scenario depends on it to comply with legal requirements and maintain the safety levels within the standards required by both the operator and ANAC.

The Brazilian regulatory agency recently modified the rule that regulates the contingency fuel, allowing it to be equivalent to 5% of the trip fuel for airlines with an active fuel monitoring program (ANAC, 2020). This reduction clarifies that the agency and the Brazilian operators align with ICAO practices and recommendations and work towards an even safer and more efficient operation.
Regarding in-flight fuel management, the RBAC 121 paragraph 121.648 recommends the fuel's continuous monitoring throughout the flight. It also states that no aircraft is allowed to land with less than the final reserve fuel in its tanks. However, it does not include the guidelines published in 2015 by ICAO, in Doc 9976, which encourages CAAs to adopt the committing to the destination policy in their regulations to provide more options for the pilots during the final phase of their flights. Therefore, it does not highlight the possibility for the PIC to use part of the alternate fuel to perform the landing at the destination airport. (ANAC, 2020).

Concerning the lack of clarity for this regulation's aspect, the three major Brazilian airlines proceed by their means on the in-flight fuel management matter. Those companies will be referred to as Airline A, Airline B, and Airline C, regarding their policies' confidentiality.

Airline A adopts a more restricted model than ICAO's, not leaving much room for broader utilization. Airline B adopts no committing to the destination policy nor cites this resource in any of its operational manuals. Airline C, on its side, utilizes an approach in its publications that is very similar to what is recognized on ICAO's Doc 9976.

The three examples above expose how heterogeneous the current legislation's interpretation is, proving an omission regarding this topic in the current regulation concerning in-flight fuel management.
Summary

The current Brazilian civil aviation regulation (notably the RBAC 121) does not prohibit nor authorize the possibility for the flight crew (through the PIC in compliance with pre-defined requirements) to proceed to land carrying less fuel than the Minimum Fuel Over Destination (MFOD), which is the amount of alternate fuel plus final reserve fuel. That means burning some of the alternate fuel to land at the destination aerodrome; what would possibly happen with a higher fuel quantity in the tanks than that remaining after landing at the alternative airport. Once all the requirements are met, landing with more spared fuel inside the wings means better safety and efficiency margins (Drees, Mueller, Schmidt-Moll, Gontar, Zvirglmaier, Wang, Straub, 2017).

This omission in the legislation impacts pilots' in-flight fuel management, sometimes causing unnecessary diversions, reducing both the safety margin and the overall system's efficiency. The more fuel quantity in the tanks, the longer the holding time to deal with unpredictable situations at any airport. Moreover, the absence of such a policy contributes to an increase in the airline's costs associated with unnecessary diversions.

The project intends to change the Brazilian regulation concerning in-flight fuel management so that the committing to the destination policy is clearly defined. It also aims to align two vital premises that would allow ANAC, through its regulations, to fulfill its central role. Firstly, this project would promote a safe environment for the agency's entire region, following ICAO guidelines and recommendations. Furthermore, this amendment would help ANAC to ensure that its regulations enable companies to seek efficiency continuously. Such administrative conduct places the Brazilian agency as
a vibrant and dynamic partner for the airlines and stakeholders by guiding and facilitating more effective operations through updated standards and trends instead of presenting out-of-date obstacles to the aviation industry development. The explicit adoption of the *committing to the destination* policy would play a significant role in the ongoing process of evolving regulations for the Brazilian civil aviation industry.
Chapter III
Methodology

As a first step in the initial methodological development process, researchers have defined three research questions. Each of them served as a guide for the project to prove three crucial points that impact airlines' safety and efficiency. The first research question deals with a shared understanding among the pilots regarding the in-flight fuel management regulation. The second one has a safety-related approach, as it seeks to discover how much a new regulation could raise the safety margins. The last research question aims to measure the direct costs that could be avoided when applying the committing to the destination policy.

The project uses a quantitative analysis regarding the results obtained from a survey carried out among Brazilian airline pilots. The analysis's purpose is to prove the Brazilian civil aviation regulation is not precise about the possibility of legally utilizing the alternate fuel to make landing possible at the original destination, which is an in-flight fuel policy known as committing to the destination.

Moreover, this workgroup also analyzed data obtained from two leading Brazilian airlines to highlight variables related to safety and efficiency and the possible savings that the adoption of committing to the destination could generate for the companies.

Airline pilot's Survey design

The researchers set the first research question to facilitate the project's development to prove Brazilian airline pilots do not entirely understand the regulation in force on the subject. It was defined as shown below:
Do Brazilian airline pilots have a common understanding regarding in-flight fuel management "committing to the destination" legal possibility?

Consequently, the researchers surveyed Brazilian airline pilots to obtain data about each aviator's perception of the current in-flight fuel management regulation. The survey was run in Portuguese so that misunderstandings among the non-English speaker respondents would be minimized. It was then translated to English for this work's purpose. The researchers also made a prior assessment with 30 Brazilian airline pilots. The intention was to collect opinions and feedback regarding the survey to check if it was clear, objective, and met the research objectives. Among the initial group, all concluded that the study was adequate for the project's target.

The survey was widely disseminated by one airline pilot association and sent to virtual aeronautical communities across the country. The initiative's goal was to reach the 6,253 airline pilots working in Brazil (ANAC, 2020).

The survey (Appendix A) consisted of three questions. The first two intended to certify that the participant currently flies or worked as a flight crew member in Brazilian and foreign airlines. It is noteworthy that many Brazilian pilots are working or had been working for foreign airlines, which adopted committing to the destination as an operational policy. Therefore, these initial questions sought to separate Brazilian pilots through these two types of professional backgrounds so that the survey results were not affected by individual biases from airline aviators with flying experience in companies not regulated by the RBAC 121. The third question concerned the possibility of applying
the committing to the destination policy in Brazil. To make the understanding of this question more accessible, the researchers created this scenario, as showed below:

You are in a descent procedure inside the terminal area to a single runway destination airport, operating under perfect weather and with no worsening forecast. The alternative airport also has only one runway and are in ideal weather with no worsening predictions, as well. You estimate to land at the destination with 3,100 kg in the tanks. The Minimum Fuel Over Destination is 3,000 kg (MFOD means the minimum fuel planned by FOO to proceed to the alternative, which is equivalent to the 2,000 kg Alternate Fuel + 1,000 kg Final Reserve Fuel).

During the descent, the air traffic controller informs that you will need to carry out a ten-minute holding procedure due to traffic flow control. From your experience, this estimate given by the ATC is indeed reliable. However, considering the controller’s waiting time, you calculate that you will land at the destination airport with 2,500 kg in the tanks, 500 kg below the MFOD.

After reading the scenario carefully, the respondents answered about the legality of using part of the alternate fuel to land at the destination airport, considering the Brazilian regulation in force. Pilots had to choose one of the four answers available. They were: Yes; No; I do not know; The regulation in force is not clear on this matter. The replies sent by the participants allowed a thorough analysis of the acquired data to clarify whether the flight crews have different understandings concerning the Brazilian regulation, besides the possible outcome that each pilot could have chosen for a situation
similar to the survey scenario. It is noteworthy that the participants were not identified so that their answers' confidentiality would remain assured.

To make a statistical inference, the researchers added the number of pilots from the three major airlines to the one from the largest regional airlines in Brazil. Besides, seven other small companies operating cargo and passengers under RBAC 121 were also considered. Thus, it was possible to obtain the total number of airline pilots at the end of 2019 (ANAC, 2020). Altogether, those ten companies represent the entire Brazilian airline market, encompassing 6,253 airline pilots representing the research population. As part of the methodology, the researchers had to calculate the minimum sample required to validate the survey. The goal was to achieve acceptable industry standards requiring a 95% confidence level and a 5% error margin. It means that on 95% of the occasions where this research is carried out, the result will be practically the same. The error margin ensures the range of the population's responses that could deviate from the sample ones. Therefore, the study considered 362 pilots as the minimum number of responses required to comply with all the accuracy criteria; otherwise, the survey would not yield useful statistics results.
Airlines data

The researchers also intended to prove that the committing to the destination policy could allow cultural development to increase the Brazilian airlines' safety and efficiency levels. Hence, they elaborated two additional research questions that aimed to discover and quantify how much a change in the regulation could benefit these two aspects. The research questions went as follows:

*How much room could this policy provide pilots to handle unforeseen events?*

*How much could this policy reduce the airline cost regarding diverted flights?*

Historical data were obtained from two out of the three leading Brazilian airlines' databases, which represent more than 60% of the Brazilian domestic market (ANAC, 2020), as presented in Figure 7:

(Figure 7 – Brazilian market share – December 2019.)

The dataset comprises information such as the planned alternate fuel, the landing fuel in the alternative airdrome, planned final reserve fuel, and the number of diversions
per year. The objective was to analyze how pilots have carried out in-flight fuel
management over the last three years through the descriptive statistics outcomes for the
operational numbers. Nonetheless, the data analysis also intended to quantify the safety
and efficiency of the current policy. Such a study is crucial for a better understanding of
the potential benefits of the ICAO's recommendation adoption and how it could boost
these two operational-financial aspects. An example of a useful data interpretation is
quantifying the average operating cost generated by a diverted flight.

The airline data analysis aimed to transform numbers into useful information that
facilitates understanding of the safety margin increase and cost reduction. The researchers
calculated the mean and standard deviation of alternate flight time for all flights diverted
to the alternative airport. Bearing in mind that the committing to the destination policy
could only be applied when the landing is assured and with favorable weather, the
initially planned alternate fuel could have been used to manage possible unforeseen
situations at the destination airport. Instead, the flights that proceeded to their alternates
got there with less fuel, reducing the management margins for unpredictable events.

The researchers reinforce for this project's purpose that the probability of
unexpected events happening is directly proportional to the number of landings and
takeoffs at a given airport, as well as the time of risk exposure. In other words, the earlier
the aircraft is on the ground, the less likely it is that an undesirable event takes place.
Therefore, diverting to the alternative airport increases the flight time and the exposure to
unforeseen situations' risks, considering a scenario that would allow landing at the
destination airport even with fuel below the MFOD.
The researchers also took into account the average cost regarding diverted flights. Hence, it becomes possible to take an efficiency-oriented approach since landing at the destination airport prevents tons of kerosene from being burned. It also reduces additional expenses such as navigation and landing fees, crew labor, maintenance, and all types of passenger support extras costs. The researchers' objective was to measure at least part of those costs that the committing to the destination policy could avoid.

**Airport data**

It is challenging to talk about safety in a scenario where an unforeseen event could completely change the pilot's decision-making process in situations where the crew does not have a further alternate. Therefore, the more fuel quantity on board, the better the chances of adequately managing those conditions.

To clarify the impact that an unforeseen issue could have on flight safety, the researchers contacted some airport authorities among Brazil's busiest airports to obtain statistical data that could quantify these events. Therefore, the researchers prepared a query to these authorities containing five questions regarding 2017, 2018, and 2019. These questions intended to identify the runway operations suspension average time related to unforeseen events, meteorological reasons excluded. This exclusion was due to the impossibility of using the committing to the destination policy in adverse weather cases. Hence, the questionnaire tried to separate the unfavorable meteorological events from other situations, such as runway inspection due to bird strike and electrical failure at the airport. The questions were as follows:
- Number of times that the airport had to suspend the landing and takeoff operations (unscheduled suspensions) due to adverse weather.

- Number of times that the airport needed to stop operations (unscheduled breaks) for any reason not related to adverse weather (e.g., runway inspection due to bird strike, general electrical failure, beacon failure, bomb threat, among others).

- Average time for landing and takeoff operations suspension due to non-meteorological events.

- Average time for landing and takeoff operations suspension, specifically considering runway inspection due to "bird strike."

- Total number of annual movements (landing and takeoffs).

These data collection made it possible to calculate the annual average of unforeseen events per year and the average duration of landing and takeoff operations suspension for each event. The data also identified and separated these events from the total number of operations interruptions, including weather conditions.

The researchers intended to make a joint analysis between the airlines’ data and the airports' information. Thus, it was possible to convert alternate flight time into holding time close to the destination and compare it with the airport's landing and takeoff operations suspension average time. Considering that the risk of an unforeseen event is similar regarding the destination airport and the alternate airdrome, it was feasible to quantify how much the committing to the destination policy will increase the pilots' holding margin.
Moreover, the researchers assessed data from the National Aeronautical Accidents Investigation and Prevention Board (CENIPA), the highest federal organ responsible for investigating and dealing with aeronautical accidents and incidents in Brazil, among other crucial aviation industry duties. The goal was to learn deeper how expressive it was to fuel emergencies among the airlines’ operations in the last ten years (2010-2019).
Chapter IV
Project Outcomes

The researchers present the study's outcomes in three parts. The objective is to provide a better understanding of the project's initial scope. It also clarifies the correlation between safety and efficiency once applying the committing to the destination policy.

The first part shows data from the survey conducted with Brazilian airline pilots and demonstrates that they do not clearly understand the regulation in force. The second and third parts aim to clarify the increase in the safety margin to handle unforeseen events and the cost reduction related to avoiding diverted flights. All of them were accomplished through data provided by two of the three largest Brazilian airlines, which will be called Airline A and Airline B for confidentiality reasons. Hence, the researchers intended to highlight the positive impact of adopting a Brazilian aviation industry's committing to the destination policy.

Pilot Survey

The research carried out with Brazilian airline pilots aimed to prove that there is no shared understanding among these professionals regarding in-flight fuel management's current regulation. The researchers considered the survey's total population of 6,253, which is the number of pilots from all the Brazilian airlines under RBAC 121. These companies represent the full domestic flights market share.

It was necessary to obtain 362 responses to reach the industry's standards for statistical inferences, which corresponds to a 95% confidence level and a 5% error margin. Although it is impossible to know how many professionals were contacted by the survey, 461 pilots answered the questions, equivalent to 7.37% of the Brazilian airline
pilots. It was well above the minimum number required, which guaranteed the survey's reliability and accuracy and allowed a quantitative analysis to represent the aviators' general understanding of this matter.

The researchers defined a simple daily basis scenario for any airline pilot. The respondents were able to choose one out of four options regarding the legal possibility of landing at the destination airport, considering the given plan. A: Yes, B: No, C: I do not know, and D: The regulation in force is not clear on this matter. Figure 8 displays the final results, exposing the pilots' divergence concerning their understanding of the current in-flight fuel management regulation.

**Pilots Survey Results**

![Figure 8 – Pilots Survey Results in percentage.](image)
The researchers scrutinized the data and concluded that only 42% of the pilots would have landed at the destination airport. The aviators that opted for option A demonstrated that they understand that it is legal to land at the destination aerodrome, even below the *Minimum fuel over destination* (MFOD). In other words, less than half of the respondents would apply the *committing to the destination* policy in their decision-making processes. The researchers also concluded that the pilots who chose options B, C, and D would have flown to the alternative airport since they understand that landing at the original destination with less fuel than the MFOD is not feasible. Therefore, 58% of aviators would have diverted. Among them, 42% understand that sticking to the destination airport would be illegal, 12% conclude the regulation is not precise enough on this topic, and 4% states lack of knowledge concerning the current law.

It was also clear that pilots who had already flown abroad did not contribute to a different outcome since most of these aviators also chose not to land at the destination airport. The researchers concluded that the survey statement made it clear that the scenario only referred to the Brazilian reality. Hence, those foreign airline-experienced Brazilian pilots responded by restricting their opinions to the local regulation, not being affected by the international ones.

The project's approach highlights that all pilots would not have a second alternate airdrome available once their option was made, regardless of the flight crew's final decision. Those who opted for option A would have to land at their destination, and those who opted for B, C, and D would have no choice other than landing at the alternative airport. However, considering the survey scenario, 58% of them would land at the alternative, a single-runway airport in good weather, with a fuel quantity very close to the
final reserve fuel, that is, with a little more than 30 minutes of flight time. The 42% who would land at the destination would also be facing a single-runway airport operation under fair meteorological conditions. However, they would still count on a 75-minute flight endurance or so. That represents around 45 extra minutes of flight time compared to the option to proceed to the alternate airdrome. This additional fuel allows pilots to experience an ampler opportunities' scope to manage any unforeseen events, such as a runway inspection caused by a bird strike or an airport power shortage.

The first research question was designed to facilitate the survey data interpretation and clearly understand the results. *Do the Brazilian airline pilots have a common understanding regarding in-flight fuel management “committing to the destination” legal possibility?* The researchers concluded that the Brazilian airline pilots do not have a shared sense of the in-flight fuel management regulation by analyzing the survey outcome. The apparent divergence in the pilots' responses leaves no doubt about the plurality of opinions related to the topic.

**Safety perspective – Airlines data**

The researchers collected information from two major Brazilian airlines named Airline A and Airline B for confidentiality reasons. The years 2018 and 2019 were chosen so that the coronavirus pandemic's negative effect did not impact the final results.

Data concerning alternate flight time, alternate fuel, and final reserve fuel were used to make descriptive statistics. Thus, the researchers identified the values referring to the mean, median, and standard deviation of the alternate flight time.
Airline A

The researchers could not access the 2018 dataset for this airline, so all the numbers and statistics only refer to 2019.

Airline A experienced 4,113 flights that had to proceed to the alternative airport. Considering a total of 243,946 flights the company performed during this period, they represented 1.68% of the airline's annual network.

Regarding the 4,113 diverted flights, the researchers considered four of them as outliers. They were dispatched with an alternate flight time of more than 170 minutes, an unusual fact in that airline's regular operations. Therefore, for descriptive analysis, the researchers took into account 4,109 diverted flights.

For the descriptive statistics, the mean and median were 53 minutes. The shortest alternate flight time was 21 minutes and the longest 140 minutes. For Airline A, the standard deviation was 13 minutes. It meant that 68% of the alternate flight time ranged from 40 to 66 minutes (one standard deviation), and 95% of these flights had an alternate flight time between 27 and 79 minutes (two standard deviations).

Below are one table and two figures referring to airline A descriptive statistics that help in visualizing the referred data:
## Airline A - Descriptive analysis - Summary

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternate flight time (minutes)</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>53</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0</td>
</tr>
<tr>
<td>Median</td>
<td>53</td>
</tr>
<tr>
<td>Mode</td>
<td>45</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>13</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>178</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2</td>
</tr>
<tr>
<td>Skewness</td>
<td>1</td>
</tr>
<tr>
<td>Range</td>
<td>119</td>
</tr>
<tr>
<td>Minimum</td>
<td>21</td>
</tr>
<tr>
<td>Maximum</td>
<td>140</td>
</tr>
<tr>
<td>Sum</td>
<td>219338</td>
</tr>
<tr>
<td>Count</td>
<td>4109</td>
</tr>
</tbody>
</table>

Table 1 – Airline A descriptive statistics results.

**AIRLINE A – DIVERTED FLIGHTS - 2019**

![Probability Distribution](image)

Figure 9 – Airline A probability concerning diverted alternate flight time (minutes) during 2019.
Airline B

The researchers had access to alternate flights for the years 2018 and 2019. However, some of these data came without information regarding the final reserve fuel, making their use in the statistics unfeasible. Besides, the researchers identified six flights that were dispatched with an alternate flight time of more than 120 minutes, an unusual fact for Airline B. So, these flights were considered outliers and were not taken into account in the statistics.

The researchers considered 1,500 flights that diverted to the alternative airport over 2018 and 2019. Due to the lack of data concerning part of the flight totals, it was
impossible to identify Airline B's flight network percentage that proceeded to the alternate.

The researchers found Airline B's mean alternate flight time of 58 minutes, the median of 57 minutes, and the standard deviation of 13 minutes through descriptive analysis. The shortest alternate flight time was 27 minutes and the longest 119 minutes. Compared to Airline A, the mean alternate flight time was 5 minutes longer, with an identical standard deviation. The researchers expected those results since both airlines have similar networks, and the alternate airports chosen by their respective FOOS follow an operational pattern. Considering Airline B, 68% of its alternate flight time ranged from 45 to 71 minutes (one standard deviation), and 95% of these flights had an alternate flight time between 32 and 84 minutes (two standard deviations). Like Airline A, Airline B had nearly identical values between mean and median, which means a normal distribution of its alternate flight times. The table and figures below help in visualizing these statistical data:

<table>
<thead>
<tr>
<th><strong>Airline B - Descriptive analysis - Summary</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternate flight time</strong></td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Standard Error</td>
</tr>
<tr>
<td>Median</td>
</tr>
<tr>
<td>Mode</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Range</td>
</tr>
<tr>
<td>Kurtosis</td>
</tr>
<tr>
<td>Skewness</td>
</tr>
<tr>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
</tr>
<tr>
<td>Sum</td>
</tr>
<tr>
<td>Count</td>
</tr>
</tbody>
</table>

*Table 2 - Airline B descriptive statistics results.*
Figure 11 – Airline B probability concerning diverted alternate flight time (minutes) during 2018 and 2019.

Figure 12 – Airline B - Number of events per alternate flight time during 2018 and 2019.
**Safety perspective – Airport data**

The researchers obtained data regarding 2019 from one of the ten busiest airports in Brazil, which experienced more than 77,000 movements in that period. The airport administration only started making a statistical control of the unscheduled runway closing periods in 2019, so it was impossible to access data from 2017 and 2018. To better visualize the airport's operating profile, Figure 13 below identifies the operation types during 2019 (DECEA, 2020):

![Type of Operation - 2019](image)

*Figure 13 – Type of operation during 2019.*

This airport has more significant landing and takeoff movements during business days than during the weekends. Figures 14 & 15 below demonstrate the comparison between these data and the airport's hourly activity (DECEA, 2020):
The researchers had access to all data referring to the suspension of landing and takeoff operations due to unforeseen events. There were 16 bad weather events and 134
non-meteorological occurrences. Among the ten types of unscheduled interventions, the most common type was bird strike events over the runway, which happened 64 times throughout the year. The table below lists all unscheduled events over one year and their respective runway closing averages.

<table>
<thead>
<tr>
<th>KIND OF OCCURRENCE</th>
<th>NUMBER OF EVENTS</th>
<th>AVERAGE SUSPENSION TIME (HH:MM:SS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRONE</td>
<td>2</td>
<td>00:13:00</td>
</tr>
<tr>
<td>FOREIGN OBJECT</td>
<td>13</td>
<td>00:08:51</td>
</tr>
<tr>
<td>FAUNA SIGHTING</td>
<td>46</td>
<td>00:07:01</td>
</tr>
<tr>
<td>FAUNA COLLISION</td>
<td>64</td>
<td>00:05:45</td>
</tr>
<tr>
<td>EXTERNAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INFLUENCES</td>
<td>2</td>
<td>00:28:30</td>
</tr>
<tr>
<td>CONSTRUCTION</td>
<td>1</td>
<td>00:12:00</td>
</tr>
<tr>
<td>MILITARY OPERATIONS</td>
<td>2</td>
<td>00:20:00</td>
</tr>
<tr>
<td>AIRCRAFT FAILURE</td>
<td>3</td>
<td>00:09:40</td>
</tr>
<tr>
<td>RUNWAY PAVING</td>
<td>1</td>
<td>01:08:00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>134</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Table 3 – Unscheduled occurrences during 2019.*

It was possible to note that only five out of 134 events had a runway operations suspension average time of 20 minutes or more. The researchers also identified a single cause that kept operations suspended for more than 50 minutes, which required unscheduled asphalt paving work due to a hole in the runway. This event maintained the runway closed for 68 minutes.
Safety perspective - Summary

To fully understand the outcomes regarding a safety approach, it is essential to remember that the committing to the destination policy requires an assured landing in the prevailing and immediate forecast weather conditions. It means that pilots must assess reasonable certainty of landing before deciding to burn the alternate fuel to land at the destination airdrome. After all, deciding on committing to the destination or going to the alternative airport are options that do not provide an additional alternate airport. Both decisions imply having only one airdrome at the pilot's disposal.

Depending on the alternative flight time and characteristics, it is unlikely to have a reasonable certainty of landing for an arrival that will happen on average, between 53 and 58 minutes ahead. Hence, this "reasonable certainty of landing" applies only to the destination airport when the aircraft is already in its vicinity. In this scenario, all fuel beyond the final reserve positively contributes to the in-flight fuel management of unforeseen situations—the more fuel on board, the greater the possibilities for properly handling unpredicted events.

Considering Airline A outcomes, an average of 53 minutes could have been converted into holding time close to the destination airport to manage unforeseen situations. Airline B obtained a mean alternate flight time 5 minutes longer, with the same standard deviation. The graphics also pictures similar results. They bring the two companies closer in terms of flight management capacity for unforeseen situations once they adopt the committing to the destination policy. Therefore, considering a scenario in which no other airport is accessible, the safety margins related to in-flight fuel management would be enlarged.
The researchers compared the airport's unscheduled events and the average additional holding time the *committing to the destination* policy provides to pilots. Converting alternate fuel into holding time to manage those kinds of issues is one of the most significant benefits of this policy.

The researchers also decided to perform a conservative analysis considering Airline A's mean alternate flight time, five minutes shorter than Airline B's average. The researchers also analyzed all Airline A's diverted flights, totaling more than 4,100, over twice Airline B's sample.

When comparing the airport data with the alternative fuel that could be converted into an extra holding time, it appears that the average of 53 minutes would be enough to cover 133 out of 134 unscheduled events that took place at the airdrome. Considering an even more conservative approach, the researchers also thought two standard deviations, equal to 27 minutes. Even so, this extra fuel would be enough to cover 132 out of 134 events. It means that for 95% of Airline A's flights, the conversion from alternate fuel to extra holding time would serve to properly manage and interact with almost all the events that led to the runway closure. Considering a flight that diverted to an airport with a similar number of unscheduled events, the alternate fuel would have been burned in the route between the destination and the alternate airdrome, significantly reducing the holding time close to the landing runway. The sooner the landing occurs, the lower the risk since the probability of facing unexpected issues is related to the airport's movement and exposure time.

The figure below allows a better understanding of Airline A's mean alternate flight time and the airport events. It also highlights the two standard deviations, which
statistically encompass 95% of the diverted flights in 2019, clearly demonstrating the

gains from committing to the destination from a safety perspective.

RUNWAY CLOSURE DURATION PER EVENT x AIRLINE A ALTERNATE
FLIGHT TIME

Figure 16 – Airline A alternate fuel that could be converted to holding time versus unscheduled
airport events duration.

It is relevant to clarify that among all the fuel emergencies experienced
countrywide in the last ten years, only an insignificant percentage of those events
concerned flights operating under RBAC 121 regulation, according to CENIPA.
Efficiency approach – Airlines data

The aeronautical industry works more and more with lower profit margins due to the extremely competitive aviation market. Speaking of efficiency means reducing costs and improving productivity.

Aligned with the industry's demands, the researchers sought to translate the diverted flights into the airlines' additional expenses, thus measuring the potential savings that the committing to the destination policy could generate. These extra costs include numerous expenses, such as fuel to fly to the alternative airport and return to the initial destination, additional navigation and landing fees, labor and maintenance costs, food, and hotel expenses to passengers. Some of these different values will occur on all diverted flights, such as the extra fuel and landing fees. Others would run on specific situations, such as providing food and hotel to passengers, which only occurs in particular cases, according to ANAC's determination. Therefore, it is necessary to thoroughly analyze thousands of flights, scrutinize each one, and have an alternate flight's average cost.

Considering the accessing difficulties for some of those data, the researchers used one of the consulted airlines' previous calculations. These numbers consider the overall average cost of a diverted flight and take into account the following characteristics:

• Extra flight time between 90 and 120 minutes (including holding time and additional flight time to get the aircraft back to its schedule).
• Cost for passengers' support (hotel, transport, and food).
• Reactionary effect (flights canceled or delayed due to diverted flight).
After analyzing thousands of flights, the airline mentioned above concluded that each diverted flight's average cost approximates US$3,400. To calculate the additional cost, the researchers understood that this value has the necessary precision and reliability to demonstrate the total costs over a year regarding diverted flights.

During 2019, Airline A had 4,113 diverted flights, which generated an additional cost of US$13,984,200. Even knowing that most of these flights detoured due to bad weather, the researchers believe that adopting the committing to the destination policy would have reduced this extra cost. As it was not possible to identify the reason that led the pilots of the analyzed flights to proceed to alternative airports, it was difficult to measure the proposed policy on these numbers precisely. However, for a better understanding of efficiency, the researchers analyzed a conservative 5% reduction in diverted flights, reducing US$699,210 in the airline's annual operating costs.

Airline B had part of its flights disregarded due to the lack of useful data. However, 1,500 diverted flights were considered in the descriptive analysis. As the aircraft type used in the two companies' calculations are similar, and both act in the same market, the researchers adopted the exact cost of US$3,400 for each diverted flight. These flights increased operating costs by US$5,100,000 over 2018 and 2019, but these extra expenses cannot be considered as the total cost of Airline B diverted flights in the period.
Chapter V
Conclusions and Recommendations

This project's purpose was to demonstrate that the committing to the destination policy can simultaneously contribute to the flight's safety and efficiency by disclosing the pilot's lack of common understanding regarding the current in-flight fuel management regulation. The researchers also pointed out that this policy is already adopted in many regions worldwide, following the ICAO's recommendations and guidelines. Hence, pilots could use this additional tool during in-flight fuel management in their decision-making process to get a better outcome.

Conclusions

The researchers believe that the current regulation that defines standards related to in-flight fuel management is ambiguous about the possibility of adopting the committing to the destination policy. Therefore, they surveyed the Brazilian pilots' understanding to determine whether that flight group also considers it the same way. After reading a scenario prepared by the researchers, 42% of the pilots replied that they would land at the destination airport with a fuel quantity below the MFOD. In comparison, 42% would fly to the alternative airdrome, 12% highlighted the lack of precise regulation regarding the topic, and 4% answered they did not know the answer.

The survey's result leaves no doubt that the researchers were on the right track about the lack of common understanding on this topic. More than half of the pilots would have flown to the alternative airdrome and landed very close to the flight's final reserve fuel, even though the destination had the same weather conditions as the alternate airport.
The pilots' divergent opinions underscore the need to update the Brazilian regulation concerning in-flight fuel management.

Among the 6,253 Brazilian airline pilots, 461 responded to the survey. Therefore, it obtained a confidence level of 97% and an error margin of 5%, reaching the required industry's standards in statistical inference. It also ensured the outcome's level of reliability and accuracy.

The researchers also concluded that this policy positively contributes to flight safety. The use of alternate fuel to land at the destination airport increases the safety margin for in-flight fuel management of an unforeseen situation—the more fuel on board, the greater the chance of success in this unlikely scenario. The analysis of more than 5,600 flights has shown that, on average, pilots would have between 53 and 58 additional minutes to handle these unpredictable events.

The airport's statistical data was also crucial to enable a more in-depth analysis of converting alternate fuel into holding time in the destination vicinity. The researchers consider that the outcomes are sufficient to prove the safety margins improvement in handling unforeseen situations. Only one out of 134 events had a runway operating suspension time longer than the mean alternate flight time.

The researchers emphasize that this policy should only be applied when pilots have a reasonable certainty of landing at the destination, in addition to performing a careful analysis of the destination and the alternative airdromes conditions. This way, aviators would decide the best course of action from both a safety and efficiency perspective.
Regarding operational efficiency, the researchers identified significant savings potential this policy could bring to companies. The operating costs of an airline have a considerable impact on the total cost. Therefore, each kilo of fuel not burned or each navigation and landing fees avoided contributes to a more robust operational efficiency. Apart from that, removing an aircraft from its original schedule will undoubtedly cause other losses, be them financial or in the airline's image. The project also clarifies the contribution that this policy could bring to the environment, as it manages to reduce the emission of gases such as monoxide and carbon dioxide.

Recommendations

The project's conclusion recommends modifying the Brazilian regulation so that there would be an explicit mention concerning the possibility of putting into practice the committing to the destination policy, strictly following the ICAO guidelines. This project states that a clear and objective regulation would leave no room for contradictory interpretations regarding the policy application, contributing to overall operational safety and reducing the associated airlines' costs. The suggested text to be inserted in the RBAC 121, paragraph 121.648, considering In-flight fuel management, is presented as follows:

"Subject to assessing reasonable certainty of landing, the pilot-in-command (PIC) has the prerogative to decide for the use of the alternate fuel to continue to the destination airport (including possible holding procedure), to land there with not less than the final reserve fuel. The PIC will make this decision after carefully considering the
traffic and the operational conditions prevailing at the destination and alternate aerodromes. The additional circumstances to allow this decision must include:

- an assured landing in the prevailing and immediate forecast conditions (including likely single equipment failures).
- An estimated approach time or confirmation from ATC regarding the maximum possible delay.

Note: To consider a landing to be "assured," the PIC must take account of all operational considerations, including any weather deterioration forecast and apparent single failures of the ground and/or airborne facilities, e.g., CAT II / III to CAT I."

Limitations of the study

The researchers did not have access to data for the three major Brazilian airlines, which would increase the number of total diverted flights. A broader analysis of the data would have been more appropriate, despite considering more than 5,600 flights to be sufficient to prove the policy's improvement related to flight safety and efficiency. Besides, the airlines were unable to clarify the real reason for the alternate flights so that the researchers could quantify how many of them diverted due to bad weather.

Another limitation was the difficulty in obtaining data from more than one main Brazilian airport. Thus, it was not possible to measure the runways' average unscheduled closing time more accurately countrywide.

The information gained from the study

After several kinds of research during the project, the researchers concluded that this is the first work regarding adopting the Brazilian regulation's committing to the
destination policy. The data obtained from the pilot's survey, airlines, and airport aimed to provide ANAC with all the useful information to prove the advantages of this policy. Thus, it will bring the agency in line with ICAO's recommendations and guidelines, which have already been adopted by the leading aviation authorities worldwide.

**Conceptual implications**

The researchers assure that the committing to the destination policy is in line with ICAO recommendations and guidelines concerning in-flight fuel management.

**Future Implications**

The researchers believe that a future project that identifies each alternate flight's reasons would allow to more accurately quantify the savings potential that the committing to the destination policy could provide to airlines. Future research with data from several Brazilian airports would positively impact information accuracy regarding airports' unforeseen events.

The researchers also think that airlines should prepare an enlightening presentation on this topic to their pilots. Consequently, the committing to the destination policy would be widely disseminated in the flight group, demonstrating the safety and efficiency gains. Airline pilots must fully understand the topic to foster better in-flight fuel management daily.
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Appendix A
Pilot's survey

This research aims to discover the Brazilian airline pilots' opinion concerning the legality of using alternate fuel to make the landing at the destination airport feasible, according to the Brazilian legislation in force.

Question 1) Do you work, or have you worked as a pilot (captain or co-pilot) in any Brazilian airline company?
A) YES
B) NO

Question 2) Do you work, or have you worked as a pilot (captain or co-pilot) in any foreign airline company?
A) YES
B) NO

Scenario
You are in a descent procedure inside the terminal area to a single runway destination airport, operating under perfect weather and with no worsening forecast. The alternative airport also has only one runway and are in ideal weather with no worsening predictions, as well. You estimate to land at the destination with 3,100 kg in the tanks. The Minimum Fuel Over Destination is 3,000 kg (MFOD means the minimum fuel planned by FOO to proceed to the alternative, which is equivalent to the 2,000 kg Alternate Fuel + 1,000 kg Final Reserve Fuel).

During the descent, the air traffic controller informs that you will need to carry out a holding procedure for ten minutes due to traffic flow control. From your experience, this estimate given by the ATC is very reliable. However, taking into account the waiting time informed by the controller, you calculate that you will land at the destination airport with 2,500 kg in the tanks,
that is, 500 kg below the MFOD.

*Question 3*) Considering the above scenario and the Brazilian policies and regulations in force, is it possible to use part of the alternate fuel (from the quantity initially planned by the FOO to proceed to the alternative airport) to land at the destination airport? In other words, will the Pilot-in-Command be able to decide to land with 2,500 kg of fuel remaining at the destination airport, even if the MFOD would be 3,000 kg?

A) YES

B) NO

C) I DO NOT KNOW

D) THE REGULATION IN FORCE IS NOT CLEAR ON THIS MATTER.