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In flight Management - Committing to Destination

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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 (Vasigh et al., 2018).

The fuel burn reduction contributes positively to the environment, reducing harmful gas emissions, such as carbon dioxide and carbon monoxide (Li et al., 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's environment has become an excellent value for many passengers. In this regard, the airline industry alone was responsible for approximately 2.4% of all global carbon dioxide emissions in 2018 (Environmental and Energy Study Institute, 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).

On average, an aircraft will burn around 0.025kg up to 0.045kg of fuel for each kilogram carried per hour, which accounts for 2.5% up to 4.5% of the extra weight (International Civil Aviation Association [ICAO], 2014). Equalizing the Risk and Cost balance concerning fuel has been challenging for regulatory agencies worldwide and all airlines (Tang et al., 2020).

Problem

The development of modern aircraft and the entire industry's infrastructure significantly improved several systems' accuracy and reliability, such as the flight management system (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 (EAFDM, 2017). ICAO released a publication to update some guidelines that emphasized the importance of fuel planning and in-flight fuel management in the wake of this cadenced technological evolution, the Doc 9976, also known as Flight Planning and Fuel Management Manual. This manual 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).

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 at the destination airport carrying less fuel than the Minimum Fuel Over Destination (MFOD), which is the amount of alternate fuel plus final reserve fuel. Once all the requirements are met, landing with more spare fuel inside the wings means better safety and efficiency margins (Drees et al., 2017).

This omission in the legislation impacts pilots' in-flight fuel management, sometimes causing unnecessary diversions, reducing the safety margin and efficiency of the overall system. 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.

Purpose

The researchers argue for a change to the Brazilian regulation concerning in-flight fuel management. This research sought 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 Brazilian pilots do not widely use; (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 (European Union Aviation Safety [EASA], 2019), and the United Arab Emirates (GCAA, 2020); and (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.

Fuel Planning and In-flight Fuel Management

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 (ANAC, 2020b), every operator, taking into account the weather conditions available, must ensure that a jet plane has sufficient fuel to Taxi the aircraft at the origin airdrome, Fly to a destination airdrome, fuel for unforeseen situations, Fly to an alternative airdrome, fuel to carry out a holding procedure over the alternate airport, Additional Fuel uplifted to cover dispatched technical issues, and Extra Fuel uplifted due to pilot or flight dispatcher discretion. Since fuel represents one of the highest operational costs, airlines understandably seek to reduce this expense as much as possible. However, this cost depends on two factors: the fuel price and its operational efficiency (Ayra et al., 2014). As the kerosene (jet fuel) market value is beyond the airlines' control, companies must develop policies and procedures to optimize this resource, thus improving their efficiency (Singh & Sharma, 2015). 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 (Singh & Sharma, 2015). 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, reducing aircraft fuel consumption (ICAO, 2015). 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 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.

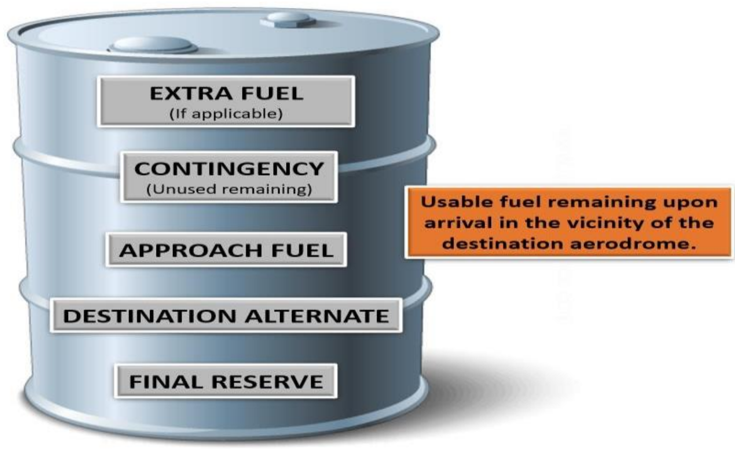
During the flight execution, the flight crew is responsible for monitoring the systems and checking fuel consumption versus the fuel planned by the flight dispatcher. Any difference between the expected and the actual fuel burned can impact the operation. As ICAO Annex 6 makes clear, the pilots' in-flight 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 et al., 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, 2020b). Many factors can contribute to the real fuel consumption being higher than the planned fuel burn, such as 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, and extra holding time due to ATC flow control (ICAO, 2015). The flight crew must 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 1.

Figure 1

Expected Fuel Onboard Close to the Destination



At this point in the flight, pilots need as many options 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 (Ayra et al., 2014): additional Air Traffic Services (ATS) charges, fuel costs, maintenance costs, handling costs, crew costs, and other costs, including passenger costs (meal, hotel, transportation, among others).

Concerning all those potential efficiency setbacks mentioned, 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. 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 and 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. The risk of unforeseen events, such as the possibility of a bird strike experienced by another aircraft a few minutes before Landing, 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 et al., 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).

The United States &European Regulations

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. There is constant action by the flight dispatchers that focus on assisting pilots by providing relevant flight information and participating in in-flight management when it comes to the United States system. 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 and Brazil, in-flight fuel management and diversions are almost the captain's responsibility. 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). *Committing to the destination* policy is already adopted by European regulation. The PIC bears the responsibility and authority to decide whether to proceed to the alternative or use the alternate fuel to land at the destination in compliance with legal provisions.

The concept of *committing to the destination* is widely used by European airlines (European Cockpit Association, 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 among the most unusual situations. 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 reducing airlines' costs and reducing 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, 2020b). Every airline pilot must be aware of this regulation and the impacts it causes on day-to-day operations.

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, 2020c). 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 can 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, 2020b). 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.

Methodology

This research used two parallel methodologies to quantify the safety and efficiency of the current policy and then evaluate how pilots have carried out in-flight fuel management over the last three years. The starting point was an analysis of historical data obtained from two leading Brazilian airlines' databases. The data represented more than 60% of the Brazilian domestic market (ANAC, 2020a), highlighting variables related to safety and efficiency and the possible savings that the adoption of *committing to the destination* could generate for the companies. 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 researchers used descriptive statistics to estimate alternate flight times for all flights diverted to the alternative airport. The researchers also took into account the average cost regarding diverted flights. The researchers then calculated 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 converted alternate flight time into holding time close to the destination and compared 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 *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 10 years (2010-2019).

In the second part, the researchers first contacted some airport authorities among Brazil's busiest airports. They administered a short survey to 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 and pre-tested with 30 pilots to identify any unclear wording or the questionnaire taking too long to administer. It was then translated to English (refer to Appendix A). The survey was widely disseminated by one airline pilot association and sent to virtual aeronautical communities across the country. Besides, seven other small companies operating cargo and passengers under RBAC 121 were also considered for a total of 6,253 airline pilots representing the research population, and the sample size consisted of 362 responses.

Project Outcomes

The first part of the analysis clarified the safety margin increase to handle unforeseen events and the cost reduction related to avoiding diverted flights. The second part shows data from the survey conducted with Brazilian airline pilots and demonstrates that they do not clearly understand the regulation in force.

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.

Airline A.

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, the researchers took into account 4,109 diverted flights. 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 Table 1 and Figures 2 and 3 referring to airline A descriptive statistics that help in visualizing the referred data:

Table 1

Airline A Descriptive Statistics Results

Airline A - Descriptive analysis - Summary	
Alternate flight time (minutes)	
Mean	53
Standard Error	0
Median	53
Mode	45
Standard Deviation	13
Sample Variance	178
Kurtosis	2
Skewness	1
Range	119
Minimum	21
Maximum	140
Sum	219338
Count	4109

Figure 2

Airline A Probability of Events per Alternate Time During 2019

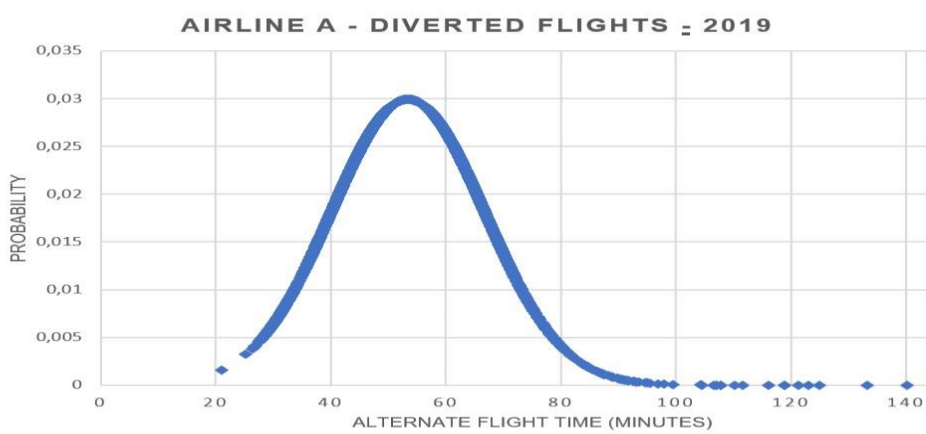
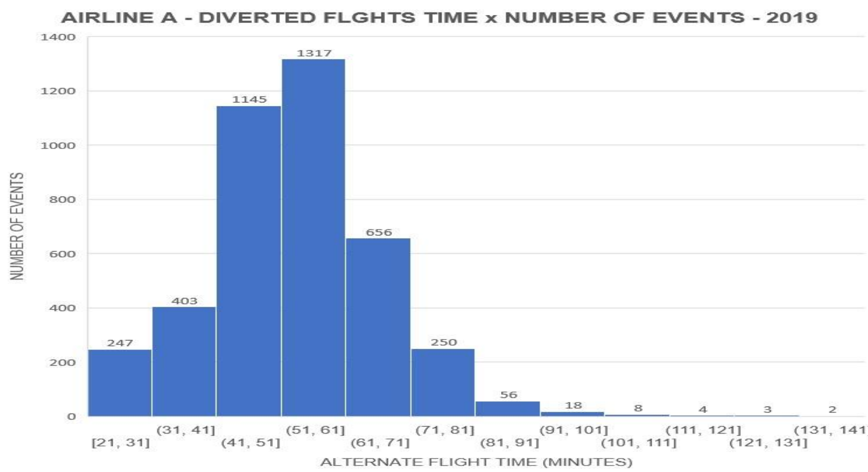


Figure 3
Airline A- Number of Diverted Alternate Flight Time (minutes) During 2019



Airline B.

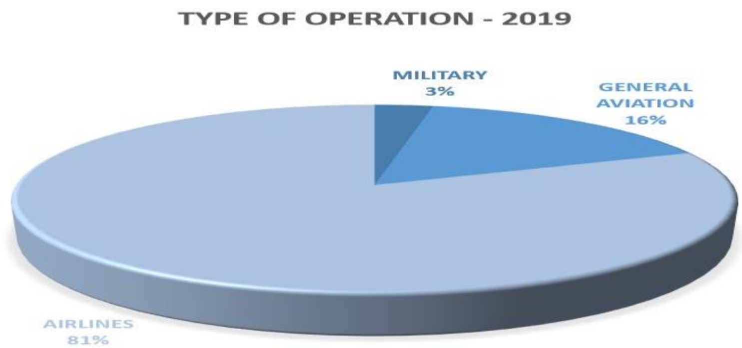
The researchers identified six flights that were dispatched with an alternate flight time of more than 120 minutes, an unusual fact for Airline B. So, these flights were considered outliers and were not considered in the statistics. The researchers considered 1,500 flights that diverted to the alternative 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.

Safety Perspective – Airport Data

The researchers obtained data regarding 2019 from one of the 10 busiest airports in Brazil, which experienced more than 77,000 movements in that period. The airport administration only started making statistical control of the unscheduled runway closing periods in 2019. This airport has more significant landing and takeoff movements during business days than during the weekends. Figure 4 identifies the operation types during 2019 (DECEA, 2020).

Figure 4
Type of Operation During 2019



Figures 5 & 6 below demonstrate the comparison between these data and the airport's hourly activity (DECEA, 2020).

Figure 5
Comparison Between Business on Business Days During 2019

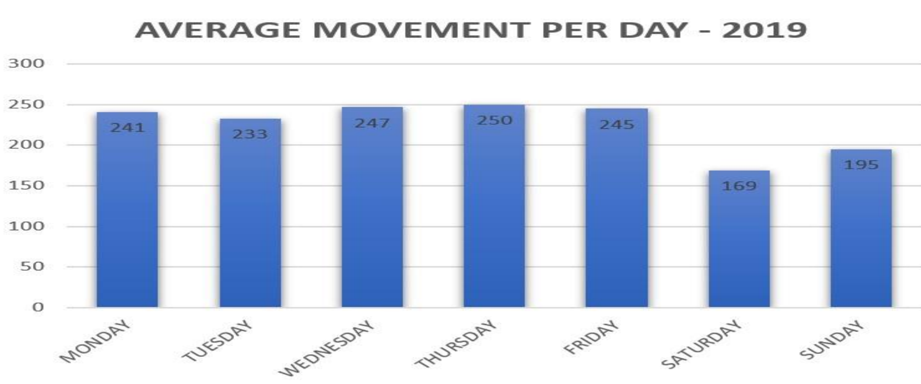
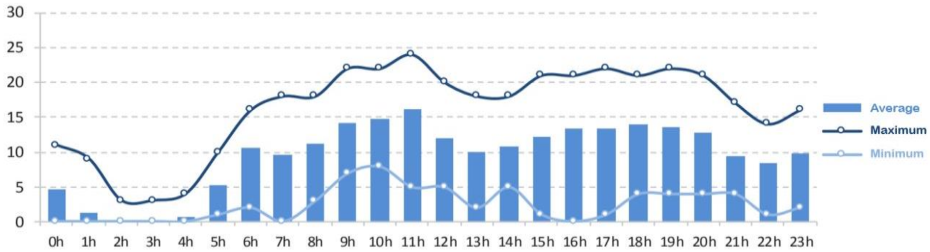


Figure 6

Hourly Average Movements and Weekend Days During 2019



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. Table 2 lists all unscheduled events over one year and their respective runway closing averages.

Table 2

Unscheduled Occurrences During 2019

KIND OF OCCURRENCE	***NUMBER OF EVENTS***	***AVERAGE SUSPENSION TIME (HH:MM:SS)***
DRONE	*2*	*00:13:00*
FOREIGN OBJECT	*13*	*00:08:51*
FAUNA SIGHTING	*46*	*00:07:01*
FAUNA COLLISION	*64*	*00:05:45*
EXTERNAL INFLUENCES	*2*	*00:28:30*
CONSTRUCTION	*1*	*00:12:00*
MILITARY OPERATION	*2*	*00:20:00*
AIRCRAFT FAILURE	*3*	*00:09:40*
RUNWAY PAVING	*1*	*01:08:00*
TOTAL	***134***	

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.

To fully understand the outcomes regarding a safety approach, it is essential to remember that *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. 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 Fuels into holding time to manage those 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.

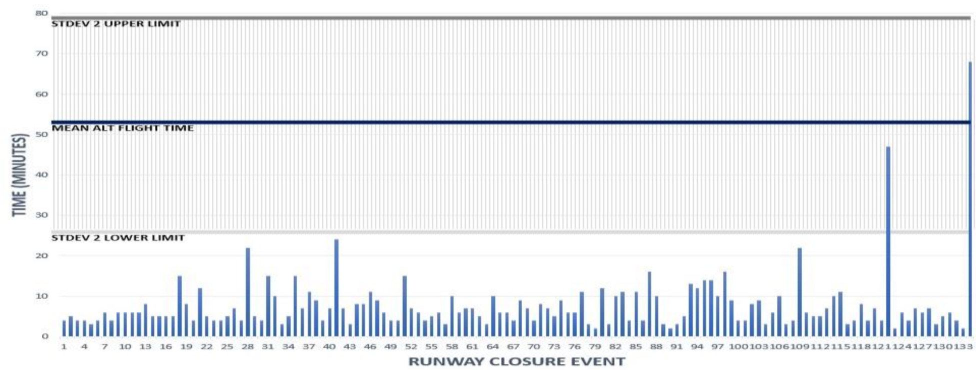
When comparing the airport data with the alternative fuel that could be converted into an extra holding time, it appears that the average of 53 minutes would be enough to cover 133 out of 134 unscheduled events that took place at the airdrome. Considering an even more conservative approach, the researchers 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.

Figure 7 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.

Figure 7

Airline A Alternate Fuel could be Converted to Holding Time Versus Unscheduled Airport Events Duration

RUNWAY CLOSURE DURATION PER EVENT x AIRLINE A ALTERNATE FLIGHT TIME



It is relevant to clarify that among all the fuel emergencies experienced countrywide in the last 10 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. 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, it appeared that each diverted flight's average cost approximates $3,400USD. The researchers understood that this value has the necessary precision and reliability to calculate the additional cost 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 $13,984,200USD. 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 U$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 U$3,400 for each diverted flight. These flights increased operating costs by U$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.

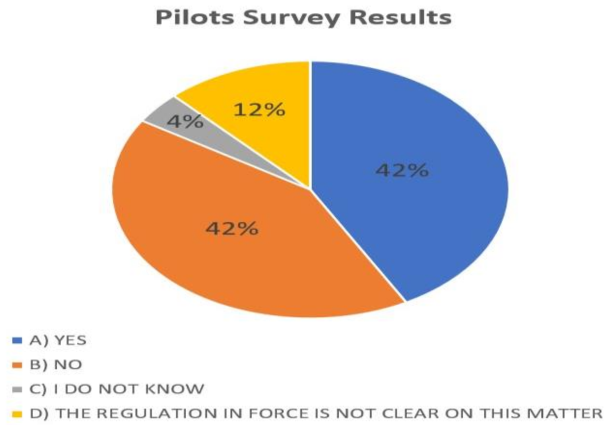
Pilot Survey.

The research carried out with Brazilian airline pilots aimed to demonstrate 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 total domestic flights market share. Four hundred sixty-one 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 (Appendix A) for any airline pilot. The respondents could 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.

Figure 8

Pilots Survey Results in Percentage



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). 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% state a 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 unforeseen events, such as a runway inspection caused by a bird strike or an airport power shortage.

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 pilots' apparent divergence leaves no doubt about the plurality of opinions related to the topic.

Conclusions

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.

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 fee avoided contributes to a more robust operational efficiency. Apart from that, removing an aircraft from its original schedule will undoubtedly cause other losses, such as financial or related to 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 researchers recommend 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. After carefully considering the traffic and the operational conditions prevailing at the destination and alternate aerodromes, the PIC will decide. 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."

The researchers presented the findings to ANAC in February 2021. ANAC is considering using the findings as an additional source of data to rewrite the regulation, either by directly changing the RBAC 121 or creating an SI (supplementary instruction) to clarify the possibility of applying the committing to the destination policy by the Brazilian airline pilots.

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. 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.

Future Implications

The researchers believe that a future project that identifies each alternate flight's reasons would allow more accurately quantifying the savings potential that *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

According to the Brazilian legislation in force, 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.

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 is 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,suc 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.