Contingency Fuel Reduction

Embry-Riddle Aeronautical University

Aviation Management Program – Class of 2019

EMBRY-RIDDLE
Aeronautical University
CENTRAL & SOUTH AMERICA

CONTINGENCY FUEL REDUCTION

by

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A Capstone Project Submitted to Embry-Riddle Aeronautical University in Partial Fulfillment of the Requirements for the Aviation Management Certificate Program

Embry-Riddle Aeronautical University

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

Capstone Project Committee:

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Abstract

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Title: Contingency Fuel Reduction

This project reviews the minimum fuel regulations for commercial passenger flights in different countries and intends to scientifically support a change in the existing contingency fuel requirement regulation in Brazil. This change represents fuel savings for Brazilian air operations, and it deploys into competitive advantage for Brazilian airlines compared to foreign air operators. The objective of this project is to provide the Brazilian civil aviation regulators with the necessary data to justify the reduction of the contingency fuel values from the current 10% to 5%. This project bases the analysis on the historical data of fuel planning and fuel consumption from two major Brazilian airlines, operating under the Civil Aviation Regulation RBAC 121. The historical data is analyzed by establishing relationships between flight planning and execution, indicating the fuel that was planned and consumed at each stage of the flight. The analysis of the impact in the contingency fuel change from 10% to 5% was made by simulating multiple scenarios capable of creating different fuel quantities for flight planning and random consumption values. The mathematical model is simulated using the Monte Carlo methodology, which calculates the amount of remaining fuel from each simulated flight

to analyze the operational risk, then support decision making. Therefore, this project presents a theoretical and practical proposal to reduce the minimum contingency fuel values required by Brazilian regulation, with a focus on safe and efficient flight operations.

Resumo

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Título: Contingency Fuel Reduction

Este projeto revisa os regulamentos mínimos de combustível para voos comerciais de passageiros em diferentes países, e pretende apoiar cientificamente uma mudança na regulamentação existente do requisito de combustível de contingência no Brasil. Essa mudança representa uma economia de combustível nas operações aéreas brasileiras, e desdobra-se em vantagem competitiva para as empresas aéreas brasileiras quando comparadas com aos operadores aéreos estrangeiros. O objetivo deste projeto é fornecer aos reguladores da aviação civil Brasileira dados necessários para justificar a redução dos valores de combustível de contingência dos atuais 10% para 5%. Este projeto tem sua análise baseada em dados históricos de planejamento e consumo de combustível de voos de duas grandes companhias aéreas brasileiras, que operam de acordo com o Regulamento de Aviação Civil RBAC 121. Estes dados históricos foram analisados, estabelecendo-se as relações entre o planejamento e a execução do voo, indicando-se o combustível que foi efetivamente planejado e consumido em cada etapa do voo. A análise do impacto da alteração do combustível de contingência de 10% para 5%, foi feita pela simulação de múltiplos cenários capazes de simular diferentes quantidade de combustível

planejado e consumido. O modelo matemático é simulado usando a metodologia de Monte Carlo, que calcula a quantidade de combustível remanescente de cada voo simulado para analisar o risco da operação e suportar a tomada de decisão. Diante disso, este projeto apresenta uma proposta teórica e prática para reduzir os valores mínimos de combustível de contingência exigidos pela legislação brasileira, garantindo segurança e eficiência nas operações de voo.

Chapter I

Introduction

Airlines flying in Brazil have their regular operations ruled by RBAC, *Regulamentos Brasileiros de Aviação Civil*, the Brazilian Aviation Civil Regulation, Part 121. The requirement states that any flight must have enough fuel to go from origin to destination (point A to point B). Also, the flight must have fuel to the alternate airport (point B to point C), plus a contingency fuel that equals the fuel quantity required to fly 10% of the flight time from A to B (ANAC, RBAC 121.645).

This 10% fuel for contingency is a number defined in the past by the local authority to cover errors during performance calculations, errors in the aircraft navigation, and also due to poor or non-existent meteorology forecasting. The sum of these errors requires additional fuel to make in-flight corrections to unpredicted situations (Hao et al., 2016).

However, the technical development in aviation brought more accuracy to the air navigation, and more reliability to the computerized flight planning performance calculations and meteorology forecasting. This evolution was possible because nowadays, the systems are integrated with other tools in the airline, increasing the database for calculations and analysis (Altus, 2009).

Today, the major commercial aircraft manufacturers equip their airplane models with navigation systems that, in conjunction with the flight plan and existing meteorology forecasting, are capable of precisely predict the atmosphere condition on every flight level and every mile of the flight.

Case Study: Contingency fuel reduction

These technological enhancements of current aviation are reducing the differences between the planned and actual fuel burn. Companies intend to keep investing in flight planning systems and modern aircraft because, in this way, airlines can save fuel with accurate and optimized flight plans applied to flight operations (Altus, 2009).

According to the ANAC, *Agência Nacional de Aviação Civil*, the Brazilian Aviation Authority, fuel is one of the airlines' highest costs. In Brazil, fuel cost has represented 24,8% to 29,5% of airline costs composition from 2015 to 2017, as shown in Figure 1. This graphic displays the cost composition of Brazilian companies, including fuel, rental, maintenance, depreciation, airport fees, amongst other costs (ANAC, 2019).

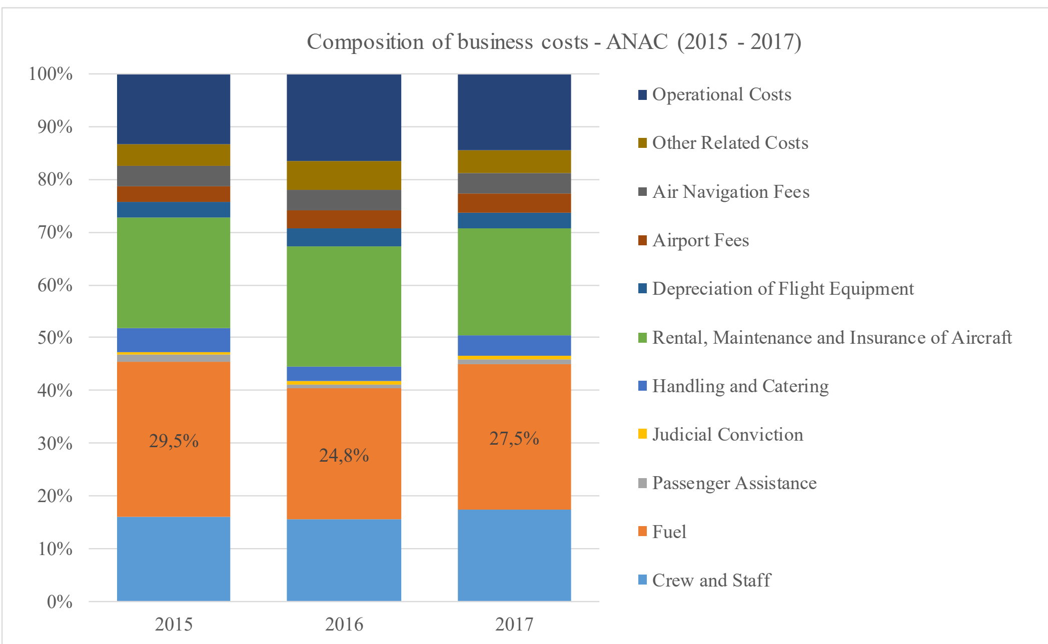

Figure 1 - Composition of business costs - ANAC (2015 - 2017)

Due to the high impact of fuel to airlines costs composition, the continuous intention to reduce costs and also CO_2 emission, almost all airlines around the world are attempting to find ways to increase fuel efficiency actions and reduce the unnecessary, or unwanted, fuel burn following ICAO recommendations (Johnson & Gonzalez,2013).

It is important to highlight that the fuel burning is part of the aircraft operation. Thus, it is part of the business, and the total fuel burnt is directly related to the aircraft's weight when flying. In general terms, airlines aim to fly with the highest number of passengers and/or cargo. Airlines must avoid all unnecessary non-paying loads, such as any unneeded fuel quantity, which would only increase weight but provides no revenue.

This dilemma brings us to the core of this project. The fuel burned has a direct correlation with the actual aircraft weight. Therefore, the more fuel carried represents more fuel burnt, and any unwanted or unnecessary weight should be avoided from the total aircraft weight. In other words, the goal is to reduce the Marginal Fuel Burn (MFB), a concept that states that the incremental fuel burnt to transport a certain load by a certain leg length. MFB is historically between 2.5 % and 5% of each kilogram of fuel per flight hour (Denuwelaere, 2012).

Civil Aviation Authorities around the world, such as Australian, Chilean, European, Mexican, etc., already identified that the contingency fuel required by their aviation regulation was beyond the real contingency fuel for safe operations. After comparing predicted versus actual fuel burnt, and the evaluation of the number of flights diverted due to fuel emergencies, those authorities have reduced the mandatory contingency from 10% to lower values as 5%. In some cases, those authorities permit the use of 3% (EASA 2019).

The FAA, in the United States, keeps 10% as a general requirement to all regular operators. However, the FAA allows airlines to define their contingency fuel requirements for domestic flights. Also, the FAA grants a deviation for international flights to keep a 10% value in the segment of the flight where the aircraft's position cannot be determined at least one time per hour. This is a special surveillance requirement.

In other words, the FAA gives the airline the responsibility to manage its policies for the application of the contingency fuel percentages (FAA, 2015).

The Brazilian aviation have similarities with the cited countries, when looking to the aircraft models operated, operational rules, software used on dispatches, crew training, etc. Therefore, it is reasonable to conclude that Brazilian fuel requirements can be reviewed to also be in line with the most updated rules.

This study proposes to scientifically support a change in the Brazilian aviation regulation, RBAC 121, to reduce the percentage of the current contingency fuel from 10% to 5% for all airlines, and to evaluate lower contingency fuel values based on specific authorization requirements. ABEAR proposed this change, and it is currently under the ANAC evaluation process.

Project Definition

This project aims to: (a) Collect data of fuel burnt in the Brazilian airlines' operations in 12 months, covering a statistically significant share of all national air traffic. (b) Study lower levels of other possible contingency fuel percentages. (c) Validate the value of 5% of contingency fuel, keeping the same existing safety levels.

Case Study: Contingency fuel reduction

Project Goals and Scope

Our project aims to demonstrate that a lower percentage of contingency fuel could be safely used in Brazilian airline operations. A rule with a lower percentage will align existing national regulations with the most modern in the world and will offer more competitiveness to Brazilian operations due to cost reductions, and supporting CO_2 emissions reductions.

Our project intends to scientifically support a change in the existing regulation of contingency fuel requirement to 5%. This change may deploy savings approximately 2,4 Million of kilograms of fuel in a year of a large Brazilian airline operation. This reduction represents around 0.25% of the annual fuel budget. The regulation change could also permit percentages lower than 5% contingency in fuel requirement, depending on special request processes individually demanded by the Airline to the Brazilian Civil Aviation Authority, ANAC.

These proposed changes will affect and bring benefits to all Brazilian airlines flying under RBAC 121 rules and will improve the aviation industry through the reduction of operational costs and would ultimately result in increasing the competitiveness with foreign carriers.

Case Study: Contingency fuel reduction

Definition of Terms

Contingency fuel	The fuel quantity required to compensate for the unforeseen factors during the flight phase. (ICAO, 2018, para 4.3.6.3)
Emergency Fuel	When the fuel available on at the last landing option is lower than the planned final reserve fuel. (ICAO, 2018, para 4.3.7.2.3)
MFB	Marginal Fuel Burn. The fuel required to transport each kg of weight over 1000 km. (Fachhochschule, 2017)

List of Acronyms

ABEAR	*Associação Brasileira das Empresas Aéreas*
ACARS	Aircraft Communication Addressing and Reporting System
ANAC	*Agência Nacional de Aviação Civil*
APU	Auxiliary Power Unit
CASA	Civil Aviation Safety Authority
CCAR	China Civil Aviation Regulations
DAN	*Documento Aeronáutico de Normas*
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FOB	Fuel on Board
ICAO	International Civil Aviation Organization
ISA	International Standard Atmosphere

MFB	Marginal Fuel Burn
RAC	*Reglamentos Aeronáuticos de Colombia*
RACP	*Reglamento de Aviación Civil de Panamá*
RAP	*Regulaciones Aeronáuticas del Perú*
RBAC	*Regulamentos Brasileiros de Aviação Civil*
RBHA	*Regulamento Brasileiro de Homologação Aeronáutica*
SARP	Standard and recommended Practices

Case Study: Contingency fuel reduction

Summary

Fuel is one of the highest airline costs, on average, about ¼ of its total costs, according to ANAC.

The Brazilian aviation legislation keeps the same fuel requirement rules today when compared to the time when Brazilian airlines did not have state of the art systems for planning and controlling their flights.

After analyzing other countries' legislations with previous positive experiences, ABEAR proposed a change in the Brazilian RBAC 121 to reduce the required contingency fuel percentage from 10 to 5%.

This study aims to scientifically support this change to demonstrate that the savings for the Brazilian Airlines will not jeopardize the quality and safety levels of flight fuel planning.

Chapter II

Review of the Relevant Literature

Fuel Planning

In the airline environment, every flight planning has the participation of the flight dispatch department. This department has, among others, the responsibility to calculate the total fuel required to complete the planned flight. This calculation takes into account the aircraft model performance, flight route, operational limitations, loads, weather conditions, and the minimum fuel required as defined by local regulation (Dispatcher, 2019).

The minimum fuel required is composed of different parts and have a unique calculation for each specific flight every day. As differences in wind, meteorology, aircraft degradation, total weight, may require more or less fuel.

The existing Brazilian regulation for airlines, RBAC 121, has in its requirements the minimum fuel planning. Paragraph 121.645 mandates that each operator must take into consideration wind and known meteorology conditions to calculate fuel for every flight of jet plane. The computation should consider having enough fuel to:

- Fly to and land in the destination airport;
- Fly a period equals to ten percent of the total time required from the origin to the destination airport (Contingency Fuel);
- Fly to and land in an alternative airport;
- Fly thirty minutes, on holding speed as applicable to the aircraft model, on a height of one thousand and five hundred feet from an alternative airport.

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The requirements of the RBAC 121.645, as written above, are graphically demonstrated in Figure 2, which also gives an overview of the composition of the minimum fuel onboard the aircraft. Any other extra fuel defined by company policies can be added to the available volume of the tank. However, this extra fuel cannot substitute the minimum required fuel.

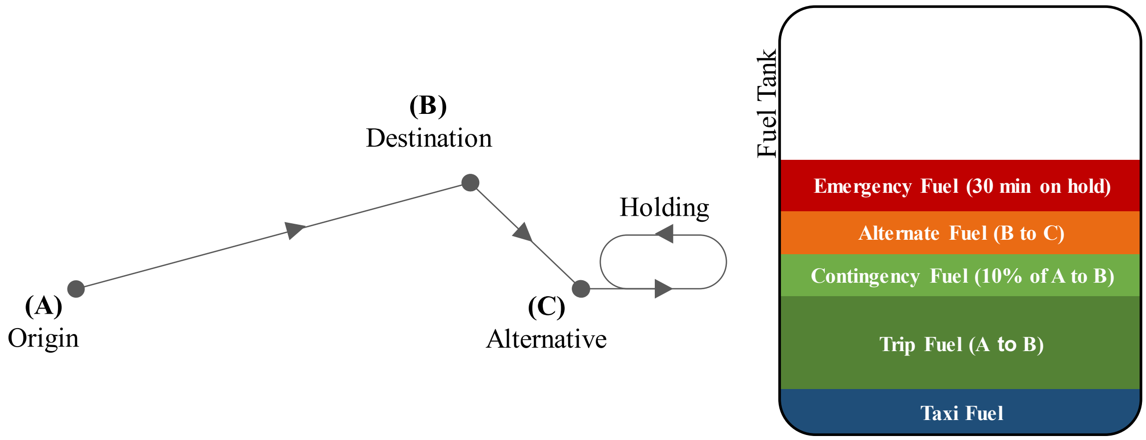

Figure 2 - Composition of minimum required fuel in Brazil

In this section, we present additional critical definitions related to the fuel planning process. Some terms may differ between countries, but usually different regulatory authorities use the same concept. (Flight Safety Foundation, 2018)

- **Block Fuel / Total Fuel On Board -** The total fuel needed to accomplish the flight, taking into consideration the Taxi fuel, the Trip fuel, the Contingency fuel, the Alternate fuel, the Final Reserve fuel, and any Extra fuel carried.
- **Taxi Fuel** - The fuel required for taxing purposes before takeoff, which usually includes APU use, engine start, and taxi time. Airlines usually have fixed values for taxi fuel depending on location and taxi duration.

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- **Trip Fuel** - The required to accomplish the flight phase of the flight, comprising from the beginning of takeoff to the landing at the destination airport. The trip fuel is calculated to have fuel enough to:
    - Takeoff
    - Climb to cruise level
    - Flight in cruise level, including any planned level change
    - Cruise to descent
    - Approach
    - Landing

  Trip fuel is also calculated based on any known air traffic restrictions that would result in delayed climb or early descent.
- **Contingency Fuel / Route Reserve** - The fuel needed to compensate for additional enroute fuel consumption caused by severe weather, routing changes, or air traffic management.
- **Alternate Fuel** - The total fuel required from a missed approach on the original destination airport to the landing at an airport defined to be used as an alternative. It is calculated to have fuel enough to accomplish:
    - From the missed approach point to the cruise level
    - From cruise to the descent at the alternative airport
    - Accomplish the approach procedure at the alternative airport
    - Landing at the alternative airport
- **Final Reserve Fuel / Holding Fuel** - The minimum fuel needed to fly 30 minutes at 1,500 feet above the alternative airport at holding speed using International

Standard Atmosphere (ISA) conditions, and taking into consideration the aircraft model performance specifications.

- **Extra Fuel** - Additional fuel defined by discretion of the Captain and/or the dispatcher following the airline policies to support strategic decisions.

Airlines are constantly looking for fuel savings by the reduction of fuel burning. One of the most used strategies is to reduce the on-board fuel to have lower final aircraft weight, thus reducing fuel consumption (Airbus,2004).

On each of the above segments of the required fuel, airlines have the means to manage and work in the reduction of fuel needed. Although they have different ways of contributing to fuel-saving, their mutual effort can bring significant fuel saving results for the Airline (Airbus,2004).

According to Boeing, companies spent 10% more fuel than required in 2011. To increase fuel efficiency, pilots can manage some phases of flight. Examples include taxi, optimizing routes, optimum flight levels, and different regimes in flights. Also, the airlines must apply procedures as fuel conservation strategies in the takeoff, climb, cruise, descent, approach, and taxi phases (Boeing, 2011).

According to AIRBUS, Taxi fuel can be reduced by applying a technique as the use of one engine for taxi and management of optimum moment to start engines (Airbus,2004).

The Trip fuel can be managed by the airlines, mainly for pilots, by the application of several actions from the takeoff to the landing. The most used techniques pass through the application of proper takeoff flaps policies. These policies can influence the fuel consumption directly, the definition and the use of shortest routes, and the use of optimum flight levels that can contribute to reducing the in-flight fuel burnt. As an example of the impact of an optimum flight level policy application, flying at 2.000 below the optimum altitude can increase 2% of fuel burn (Boeing, 2011).

Alternate fuel can be managed by airlines by the strategic choice of the alternative airports to be used for each route. Usually, airlines also take into account other costs arising from a diverted flight but still take into account the fuel required by regulation for this phase.

Extra fuel is part of the company's policies and is covered by the strategic decisions to manage any amount of additional fuel or the need to cut it.

Finally, the Final Reserve Fuel of 30 minutes cannot be reduced as it is the only supply in cases of final emergency and is mandated by ICAO Annex 6. (ANAC, 2018)

The above paragraphs reveal that airlines have a means to work and manage the fuel burnt by applying internal procedures, fuel savings techniques, and operational policies. However, airlines cannot manage the 10% contingency fuel, as it is mandatory. Even when having the accurate dispatch process and modern aircraft that could justify the reduction of this percentage, the airline is being obligated to transport extra-weight in unnecessary contingency fuel, which increases costs.

Regulatory Contingency Fuel

The existing requirement for contingency fuel in the current RBAC 121 is based on the older versions of Brazilian aviation regulation, RBHA 121, and has inherited its rules from the beginning of the Brazilian airlines' operations. The first versions, based on the FAA regulation, defined the required contingency fuel as a number enough to compensate unforeseen factors, navigation error, or even calculations error in the dispatch process. However, aviation in the world experienced the lead technological development along the last decades, changing the precision of the calculations, bringing precise navigation to the airlines, and promoting accurate meteorology forecasts (Schneider,2009).

Other regulatory agencies around the world, such as American, Australian, Chilean, European, Mexican, etc., that also use standardized rules for determining the requirements for fuel planning, have stepped forward. They evolved to a more modern approach of their legislations., based their minimum requirements on the existing rules from the International Civil Organization Association (ICAO).

According to Standard and Recommended Practices (SARP) 4.3.6.1 (ICAO, 2013), a flight shall not be initiated unless it takes into consideration the meteorological conditions and delays expected in the flight. The aircraft has enough fuel to accomplish the flight safely. Additionally, a 5% reserve fuel shall be considered for contingencies and unforeseen situations that shall not be lower than the amount required to fly for five minutes at holding speed at 450 m (1 500 ft) above the destination aerodrome in standard conditions (ICAO Annex 6, chapter 4.3.6).

The European Aviation Safety Agency (EASA) Regulation, in its Commission regulation 965, dictates technical requirements related to air operations that contain fuel regulations.

This particular part of the European regulation states that a fuel policy shall be defined by the operator to the flight planning. This ensures that every flight has enough fuel for the planned operation and enough reserve fuel to cover deviations and contingencies (EASA, 2012).

Table 1 summarizes the contingency fuel requirement adopted by the authorities from relevant aviation markets.

AUSTRALIA (CASA 29/18)	**BRASIL** (RBAC 121)	**CANADA** (TP14371)	**CHILE** (DAN 121)	**CHINA** (CCAR 121)	**COLOMBIA** (RAC 121)	**EUROPE** (ANEXX 6)	**PANAMA** (RACP 58C)	**PERU** (RAP 121)	**U.S.A.** (FAR 121)
5%	10%	10%	5%	10%	5%	5%	5%	10%	10%*

Table 1 - Percentage of contingency fuel per country/region

* Under special deviations, FAA permits the dispatch of domestic flights without contingency fuel, and international flights with 10% only in segments without determined surveillance level.

Risk Management and Assessment

A reduction in the contingency fuel results directly in less fuel onboard and may sound as a reduction on the safety level, and consequently, higher risks to the flight operations. However, airlines have a means to manage the risk by assessing, evaluating, and controlling all phases of flight, from planning and dispatch, until monitoring on real-time all flights from take-off to landing. The airline operations, including flight operations, have inherent risks, and risk management is the ability to achieve the business goals by integrating economic, environmental, and social opportunities with the business strategy keeping the operationally acceptable safety level (Wirtenberg, 2006).

Like other activities of high risk, aviation needs to have thorough and comprehensive studies for implementing new processes and procedures to evaluate implementation feasibility. One of the best ways to analyze the risks involved is through risk assessments (ICAO, 2013).

Risk assessment consists of maintaining risks at some acceptable level before the implementation. The process starts with a crucial phase of hazard identification, and after analyses, risks are set in a matrix of severity, and probability of harm or damage occur. It is noticeable that risk assessment is vital to the risk management process and is essential in the core competency of the safety professionals (ICAO, 2013).

Applying the risk assessment to the reduction of contingency fuel percentage would result in evident hazards of lack of fuel to the planned trip and the need to use the Final Reserve Fuel, entering in the emergency condition. Therefore, the risk assessment intends to raise this evident and severe hazard, while the risk management intends to find means to control and keep acceptable safety levels in the flight operations.

Simulation and Modeling

Simulation is an important tool to support risk management since the aviation industry has a high level of complexity. Several situations may affect the flight time, the flight path, the airport to be used, or even the operational procedures to be adopted to any specific situation. Through simulation, the airline can replicate the unforeseen and random reality.

Therefore, the change of the regulatory percentage of contingency fuel would require a preventive test before defining it as the new rule of the whole country operations. To add, the best way to test it is by simulating typical aviation operations in different scenarios to identify the positive and negative impacts of the modification.

Case Study: Contingency fuel reduction

Simulation is a technique widely used in operations research due to its power of taking into account the random factor in the model, approaching mathematic models to real scenarios (Ryan & Heavey, 2006).

Simulation is specially adopted in cases that no failure event is accepted after the modification of a parameter of the system, as in aviation. So any emergency caused by a change can be primarily seen in the simulation environment.

Modeling a typical daily operation in the Brazilian aviation starts by collecting operational data of real flights of Brazilian Airlines, then observing the typical fuel quantity used on dispatch, and real fuel usage of each flight. In this project, the model is simulated using the Monte Carlo methodology. This powerful tool simulates the random events that can occur in a flight, which can cause differences in fuel burning, and resulting in the use of the contingency fuel (Shreĭder, 1966).

The Monte Carlo simulation can be applied in a high number of situations, where have a historical database and need to have an aleatory condition using known variables. In another study, Andreeva-Mori and Uemura (2018) used this tool to account for various wind conditions in the descent procedure. In their research, they were looking for the influence of wind in the descent procedure, creating two strategy scenarios.

In the first scenario, the pilot does not add any thrust regardless of the path deviation. Whereas, in scenario 2, the pilot adds some to eliminate the potential steady flight level segment at 10,000 ft (Andreeva-Mori, 2018).

The result of Monte Carlo simulation presented three sample wind prediction error, with 10,000 runs, and show the difference between strategies comparing some key descent profile characteristics, as fuel burn, the flight time from the top of descent to metering fix and level segment flight time (Andreeva-Mori, 2018).

Due to the powerful computational capability of the Monte Carlo simulation, we were able to simulate real flight conditions using the airline historical database to calculate initial fuel onboard, fuel used on each different flight, and the remaining fuel on landing.

The observations of the flights' database, provided by two Brazilian Airlines, are used to determine the behavior of the random processes of the model and serve as inputs to the Monte Carlo methodology. The simulation can randomize the fuel on dispatches and fuel burnt on different flights.

The results of the simulation intend to create statistical trials and return the percentage of flight that will land with fuel onboard below the minimum level. In other words, the Monte Carlo methodology intends to simulate random scenarios to find if any percentage of flights that consumed all its fuel after reducing the contingency requirement to 5% (Shreĭder, 1966).

Summary

The legal requirement for fuel planning is separated into several distinct parts. The main ones are: Trip fuel (fuel planned to be burned from origin to destination), alternate fuel (fuel to fly from the missed approach point at the destination to an alternate airport) and the contingency fuel, which is a pre-determined percentage of the trip fuel that has to be added to the total fuel onboard. In the Brazilian legislation, it is 10%.

Case Study: Contingency fuel reduction

Airlines apply several procedures during the planning and flying phases according to techniques prescribed by airplane manufacturers. However, the only part of the fuel requirements that cannot be properly managed with a focus in savings is the contingency fuel since it is pre-determined by a legal requirement.

Some major Worldwide aviation authorities have reduced the contingency fuel requirement percentages, including EASA, FAA, and ICAO.

This study used simulation and modeling based on real flights from major Brazilian airlines to scientifically support that Airlines need less than the 10% contingency fuel in order to fly safely. The airlines will have a significant saving in their fuel costs.

Chapter III

Methodology

This project uses two parallel methodologies to evaluate the impacts of the reduction of the regulatory contingency fuel from 10% to 5%.

The starting point is an analysis of the flight's historical database, provided by two of the three major Brazilian airlines. The actual contingency fuel on departure is mathematically replaced by 5% to check the remaining fuel on landing and the general impacts of this change as a qualitative analysis.

The second part simulates multiple flights with different inputs of fuel planning (taxi fuel, trip fuel, additional fuel, etc.) and the 5% proposed rule, and use randomization to calculate the remaining fuel on landing for different conditions created by the model.

Sampling design

The analysis of flight history is based on databases provided by two of the three largest airlines in Brazil and contains operational information of six to twelve months of flights, with the total fuel planned and realized to each flight leg.

The data of fuel planned for each phase were extracted from the airlines' dispatch software, which also contains information about the route, flight time, aircraft model, and details of fuel planned to taxi, cruise, reserves, contingencies, etc.

The data of realized flights were extracted from airline communication management systems that provide logs of data generated by the aircraft ACARS, Aircraft Communication Addressing, and Reporting System.

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This system sends messages via radio communication to the airline ground base, containing among others, the time information on specific phases and the total fuel on each of these phases.

The information on the databases is a stratified sampling of the totality of the Brazilian aviation operation. The information is considered a representation of the Brazilian aviation service. Both airlines represent 60% of the total flights in the country. As calculated based on the ANAC information given by Table 2 (ANAC, 2019), the airlines have similar operational characteristics (destinations, aircraft models, routes, etc.) when compared with the other airlines, and fly under the same regulations.

AIRLINE	Flights (JUN/19)	%
AZUL	**23351**	**36.1%**
GOL	**20073**	**31.0%**
LATAM	**18744**	**29.0%**
PASSAREDO	928	1.4%
MAP	434	0.7%
TWO FLEX	416	0.6%
LATAM CARGO	317	0.5%
TOTAL CARGO	238	0.4%
MODERN LOGISTICS	166	0.3%
TOTAL	**64667**	**100.0 %**

Table 2 - Number of flights in June/2019 - ANAC

Apparatus and Procedures

Flight database - The flights' database was provided by two airlines to this project, covers six to twelve months of operations, and contains the relevant operational information to this project. Different aircraft models, operating different routes, generated the database, representing the reality of actual flight operations in the country. The models used in the database are Boeing 737, Airbus A319, Airbus A320, Airbus A321, Boeing 767, Airbus A350 and Boeing 777.

The database of actual fuel is constructed based on the information of Fuel on Board - FOB in the standard flight phases OUT, OFF, ON, and IN.

- **OUT** is the time that the aircraft is out of the gate on origin
- **OFF** is the exact time the aircraft takes off from origin
- **ON** is the exact time the aircraft touches the ground on landing
- **IN** is the time that the aircraft enters the gate on destination

The FOB on each phase comes from the aircraft systems that transmit the information via ACARS to the airline, which maintains the historical database of its operations.

However, ACARS use radio or satellite communication to send the FOB information, which are susceptible to area coverage. And there is a lack of information causing loss of fuel quantity information in the OUT, OFF, ON, and IN phases.

Therefore, the complete database was cleaned by the researcher's team to exclude non-revenue flights and flights not operated by an aircraft registered in Brazil, entries with missing or invalid data of Aircraft Model, FOB in the phases of OUT, OFF and ON, and missing or invalid data of planned trip fuel. The final database is a spreadsheet with the following information (columns):

- **ID** - To identify different entries
- **MODEL** - Aircraft model used in the flight
- **MFB MODEL** - Marginal Fuel Burn value for the model
- **FLIGHT TIME** - Duration of the flight in hours

Case Study: Contingency fuel reduction

- **PLANNED TRIP FUEL** - The planned trip fuel
- **CONTINGENCY FUEL** - The existing 10% contingency fuel
- **ALTERNATE FUEL** - The fuel planned to fly to the alternative airport
- **RESERVE FUEL** - Fuel to fly for 30 minutes over the alternate airport
- **TAXI FUEL** - Fuel planned for the taxi procedure on departure
- **EXTRA FUEL** - All additional fuel planned by discretion of the company
- **ON FOB** - Fuel on board at landing
- **OUT FOB** - Fuel on board at the gate on departure

After the data cleaning, the list remained with a total of 293,488 flights with valid data on each of the above information (columns). Following the ANAC records, in the same period, both airlines together made 371,339 flights. The confidence interval of this sample can be calculated by Yamane's sample size formula (YAMANE, 1967), and the results are presented in Table 3 of Chapter IV.

$$n = \frac{N}{1 + N * (e)^2}$$

n = Sample size

N = Population

e = confidence interval

Case Study: Contingency fuel reduction

In addition to the above information (columns), and after the data cleaning, the final spreadsheet receives the below columns with the following calculated variables to support the analysis:

- **TOTAL FUEL 10** - Total fuel on board with 10% contingency fuel

  TOTAL FUEL 10 = PLANNED TRIP FUEL + CONTINGENCY FUEL + ALTERNATE FUEL + RESERVE FUEL + TAXI FUEL + EXTRA FUEL

- **TOTAL FUEL 5** - Total fuel on board with 5% contingency fuel

  *TOTAL FUEL 5 = (1,05 * PLANNED TRIP FUEL) + ALTERNATE FUEL + RESERVE FUEL + TAXI FUEL + EXTRA FUEL*

- **USED TRIP FUEL** - Total fuel used in the flight:

  USED TRIP FUEL = OFF FOB - ON FOB

- **LAND 5%** - Total fuel on landing if the contingency fuel was 5%:

  LAND 5% = TOTAL FUEL 5 - USED TRIP FUEL

- **DIFF FOB** - Difference on Fuel On Board when comparing rules of 10% and 5% for contingency fuel:

  DIFF FOB = TOTAL FUEL 5 - TOTAL FUEL 10

- **DIFF F.BURN** - Difference on fuel burn due to the DIFF FOB:

  *DIFF F.BURN = DIFF FOB * MFB MODEL*

The target of the above calculations is to identify flights that would have fuel onboard under the minimum limits when being dispatched using five percent of contingency fuel in the planning phase. In other words, to evaluate when **LAND 5%** is smaller than **RESERVE FUEL**.

Case Study: Contingency fuel reduction

Simulation database - The simulation table uses the same original database used to create the previous spreadsheet, grouping the relevant information to the simulation model, making it useful to collect the statistical observations from historical data.

The database for simulations is a separated spreadsheet, with the following information extracted from Flight Database, and separated in different columns:

- **ID** - To identify different entries
- **FLIGHT TIME** - Duration of the flight in hours
- **PLANNED TRIP FUEL** - The planned trip fuel
- **CONTINGENCY FUEL** - The existing 10% contingency fuel
- **ALTERNATE FUEL** - The fuel planned to fly to the alternative airport
- **RESERVE FUEL** - Fuel to fly for 30 minutes over the alternate airport
- **TAXI FUEL** - Fuel planned for the taxi procedure on departure
- **EXTRA FUEL** - All additional fuel planned by discretion of the company
- **USED TRIP FUEL** - Total fuel used in the flight

Then, these two additional columns are created in the spreadsheet:

- **GROUP** - Classification of the flight per its duration:

  A - FLIGHT TIME until 1,0 hour

  B - FLIGHT TIME from 1,0 to 2,0 hours

  C - FLIGHT TIME from 2,0 to 3,0 hours

  D - FLIGHT TIME from 3,0 to 4,0 hours

  E - FLIGHT TIME from 4,0 to 6,0 hours

  F - FLIGHT TIME from 6,0 to 10,0 hours

  G - FLIGHT TIME higher than 10,0 hours

Case Study: Contingency fuel reduction

- **CONSUMPTION FACTOR** - Relation of actual and planned trip fuel:

  CONS. FACTOR = USED TRIP FUEL / PLANNED TRIP FUEL

Model spreadsheet - The model for simulation is written in a separated spreadsheet were the Excel application, Oracle Crystal Ball, can run separately for each group of flights.

The modeling is calculation of the random fuel quantities of each variable of the model (PLANNED TRIP FUEL, CONTINGENCY FUEL, ALTERNATE FUEL, RESERVE FUEL, TAXI FUEL, EXTRA FUEL, and CONSUMPTION FACTOR), respecting the historical behavior of each of data separately, to find the remaining fuel of each simulation.

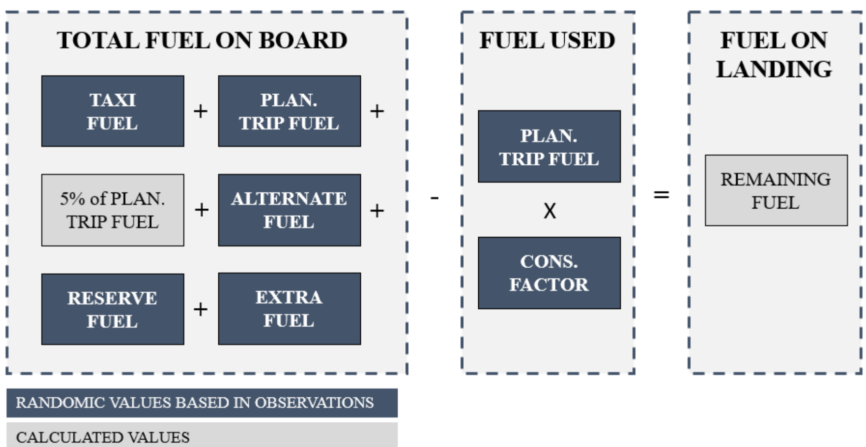

Figure 3 - Simulation model for remaining fuel with 5% of contingency fuel

The figure above illustrates the relationship between variables in the model, the calculation to find the remaining fuel of each flight, and the variables that receive the values randomized by the Monte Carlo methodology using historical data from the Simulation Spreadsheet described in the item before.

Case Study: Contingency fuel reduction

Summary

To achieve the best results to analyze the contingency fuel, two different methodologies were applied. The first was a review in historical data that was provided for two of the main companies in Brazil, and the second was a simulation of a typical flight schedule in the Brazilian industry.

The historical data can introduce and analyses the subject to motivate the reason for the study to be conducted. It was an opportunity to see if the solution proposed could be achieved and if this could generate some safety impact. During this phase, the environment was standardized in terms of premises that would be used in the next phase.

The second part of the study is the simulation, where we use historical data of different variables that can affect fuel consumption, collect data to understand the statistical behavior of them.

A mathematical model used this statistical information to simulate the remaining fuel on board of simulated flights, and compare with the minimum reserve fuel (holding fuel), to conclude if any flight could be severely affected by the change on the contingency fuel from 10% to 5%.

Chapter IV

Project Outcomes

Based on the scope of this project, the outcomes are presented in two different parts. The first one is dedicated to analyze the historical data of flights from two of the three major airlines in Brazil, and make a new assumption on the contingency fuel quantity to understand the impact of the proposed regulation change in the Brazilian aviation industry.

The second part is dedicated to the analysis of the simulation results. Multiple random scenarios were generated, with the Monte Carlo simulation methodology, to find remaining fuel quantity on the flights' destinations, and the comparison with the minimum fuel quantity required for safe operations on this phase.

Data collection analysis

Both Airline A and Airline B provided flight planning historical data and also actual flight data received automatically via ACARS from flights in the same period. This study compared both information to find pairs of "actual vs. planned" and cleaned the data using the process mentioned in the previous chapter.

These actions resulted in several flights enough to run analysis and predict results using actual data, with representativeness of 99,92% of the sample, as per Yamane's sample size formula calculation.

Table 3 provides details about sampling sizing and confidence interval calculation.

Case Study: Contingency fuel reduction

AIRLINE	Airline A	Airline B	Total
Number of flights (Sample Size)	211,839	81,649	**293,488**
Period in the sampling	12 Months	7 Months	**-**
Total flights in the period (Population)	249,663	121,736	**371,339**
Sample Size %	84.85%	67.07%	**79.02%**
Representativeness (Confidence Interval)	-	-	**99,92%**

Table 3 - Analysis of flights data sampling

However, there are several different types of flights contained in the dataset, which do not allow us to compare them directly. These flights are operated by different aircraft models, flying different distances, carrying different weights, in multiple combinations of these factors. Therefore, to better explore the data, the outcomes are presented categorized by the flight duration, which is the factor that most directly affects the amount of fuel burnt by the aircraft.

For this project, the flight durations were categorized in five different blocks, separated by one hour difference, as follows:

- Group A – Flights with a duration of 1 hour or less
- Group B – Flights with duration between 1 and 2 hours
- Group C – Flights with a duration between 2 and 3 hours
- Group D – Flights with duration between 3 and 4 hours
- Group E – Flights with a duration of between 4 and 6 hours
- Group F – Flights with a duration of between 6 and 10 hours
- Group G – Flights with a duration of 10 hours or more

Case Study: Contingency fuel reduction

This categorization reveals that the Brazilian operations have almost 70% of its operations concentrated in flights with duration up to 2 hours. If analyzing flights until 3 hours of duration, it returns a coverage of more than 90% of Brazilian flights, as shown in Figure 4.

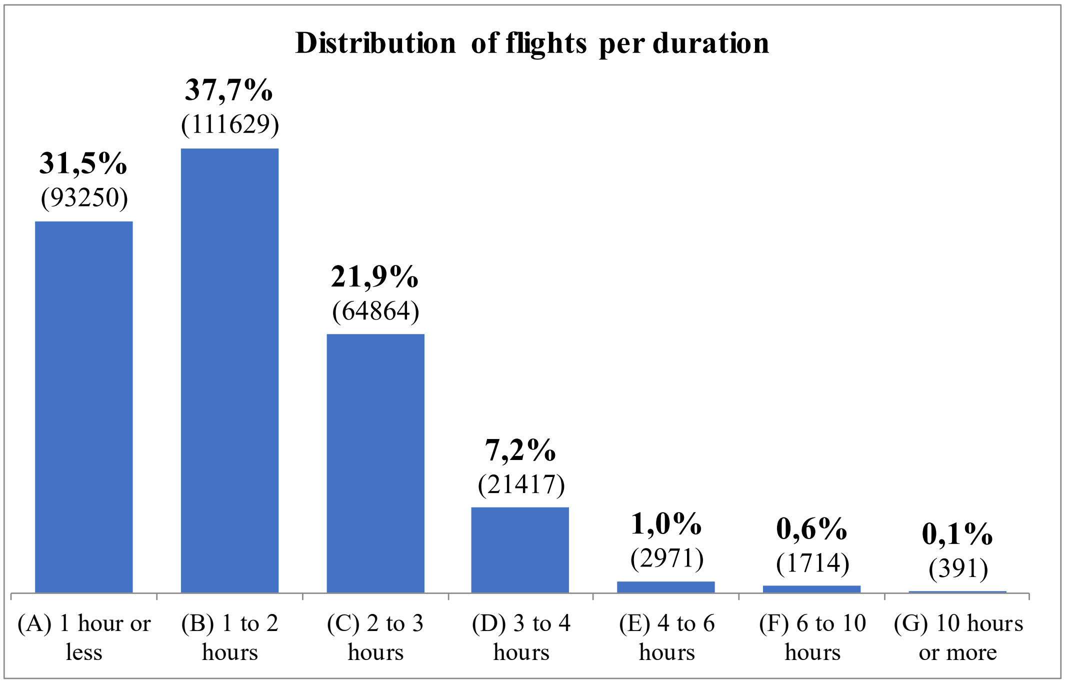

Figure 4 - Distribution of flights per duration

Flight analysis outcome

The historical data of flights provided by the airlines were used to an initial estimation of the “new” Fuel On Board (FOB) using the new proposed rule of 5% of contingency fuel instead of existing contingency fuel.

For each entry, the actual value of fuel used in the flight is deducted from the new FOB to calculate how much fuel each flight would land if it were dispatched with the modified contingency fuel of 5%.

Case Study: Contingency fuel reduction

The intuitive conclusion for reducing the contingency fuel from 10% to 5%, is that all flights should have a reduction in the fuel quantity on landing. Since the less fuel the aircraft, have in the departure, the less fuel would have in the arrival.

However, the current regulation requires 10% over the flight time, while the new proposal is 5% over the trip fuel quantity. While this last one is a direct and linear relation, the calculation over the trip fuel is not a linear relation. And for long flights, the total contingency may result in lower values when compared with the linear 5% calculation.

In general, 71% of flights had the fuel on landing reduced when compared with the current regulation. The most affected in this condition are in Categories B and C. On the other hand, approximately 29% of flights had an increase in their fuel quantity on landing. The highest concentration is in the flights in Category A. Figure 5 gives details on this analysis.

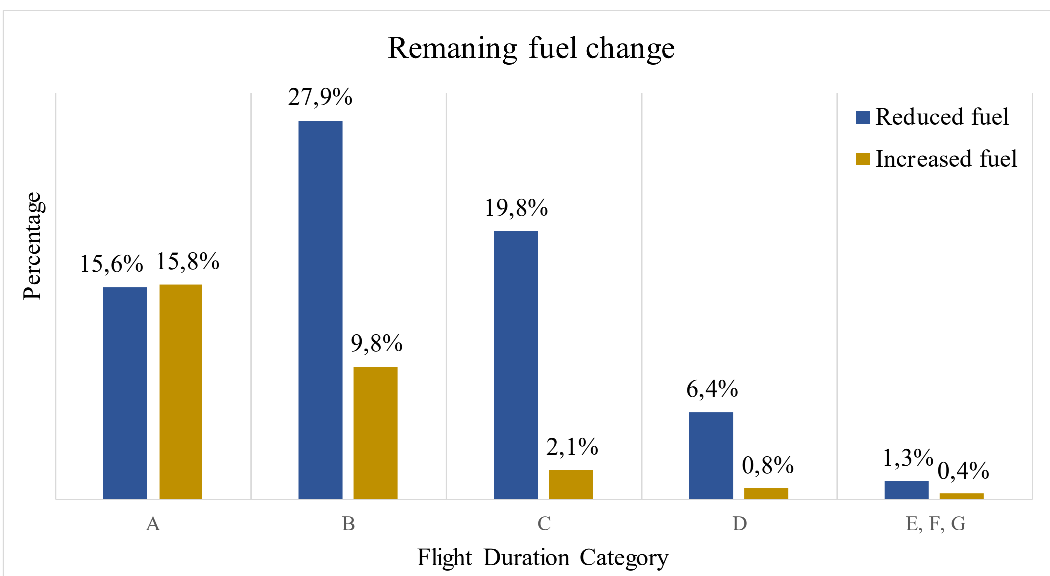

Figure 5 – How remaining fuel is affected by the change on the contingency fuel

Case Study: Contingency fuel reduction

However, even if the change of the current regulation to 5% is capable of increasing the remaining fuel quantity on the landing of almost 30% of flights, we still needed to investigate further how the other flights were impacted.

The next step was to analyze the flights that had their fuel quantity at landing decreased, and how much remained on board, to find out if any flight might be safely affected by this change.

Therefore, the researchers compared the new fuel onboard on landing, applying the 5% rule, with the final reserve fuel (holding fuel), and observed the difference between them. The objective was to check if there would be any flight with a fuel onboard on landing lower than the minimum fuel required by regulation, which could result in an emergency condition.

Figure 6 gives the number of observations of flights, grouped by the difference of remaining fuel on landing and final reserve fuel. Negative values identified situations when the flight landed below the minimum fuel required by regulation, while positive values indicate more fuel than the final reserve fuel quantity.

Case Study: Contingency fuel reduction

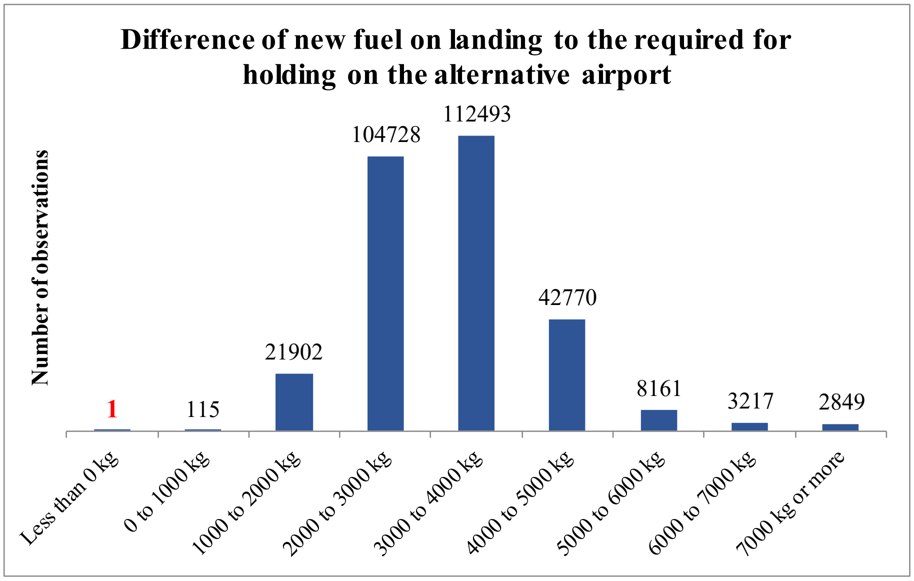

Figure 6 – Difference of fuel on landing to the required for holding on the alternative airport

It is possible to observe that after changing the contingency fuel rule, the majority of flights would land with 2000kg up to 4000kg more fuel than the minimum reserve.

The Figure reveals one isolated case in which the aircraft would land with less fuel than the minimum reserve, or in other words, in a fuel emergency condition. Regarding this specific flight, the historical data revealed that even with the current 10% rule, this flight was in a fuel emergency condition, and for that will be not considered to the purpose of this study.

Monte Carlo simulation outcomes

The Monte Carlo simulation was also divided into separated simulations for each flight category. So the effect of flight consumption differences of short and long flights will not affect the historical data collection.

Case Study: Contingency fuel reduction

The model created to this simulation requires statistical information, to run random scenarios, from the historical data of the following variables:

- Taxi Fuel
- Planned Trip Fuel
- Alternate Fuel
- Extra Fuel
- Holding Fuel
- Relation between Actual and Planned Trip Fuel, also named in this study as Consumption Factor

The observation of the above variables data determines the type of statistic distribution of the historical observation. This determination is required to define the inputs needed from each variable (mean, mode, standard deviation, etc.) to be inputted in the simulation tool.

With the support of the Excel application Oracle Crystal Ball, and using the bulti-in tool based on Anderson-Darling methodology, it was possible to determine the distribution that better adjusted for each dataset.

Table 4 presents the results of this analysis.

Case Study: Contingency fuel reduction

	Taxi Fuel	Planned Trip Fuel	Alternate Fuel	Extra Fuel	Holding Fuel	Consumption Factor
Group A	Normal Distribution	Normal Distribution	Normal Distribution	Log-Normal Distribution	Normal Distribution	Logistic Ditribution
Group B	Normal Distribution	Normal Distribution	Normal Distribution	Log-Normal Distribution	T Student Ditribution	Logistic Ditribution
Group C	Normal Distribution	Normal Distribution	Normal Distribution	Log-Normal Distribution	Logistic Ditribution	Logistic Ditribution
Group D	Normal Distribution	Normal Distribution	Normal Distribution	Log-Normal Distribution	Log-Normal Distribution	Logistic Ditribution
Group E	Normal Distribution	Normal Distribution	Normal Distribution	Log-Normal Distribution	Log-Normal Distribution	Logistic Ditribution
Group F	Normal Distribution	Normal Distribution	Normal Distribution	Log-Normal Distribution	Logistic Ditribution	T Student Ditribution
Group G	Normal Distribution	Normal Distribution	Normal Distribution	Log-Normal Distribution	T Student Ditribution	T Student Ditribution

Table 4 – Type of distributions for each historical observation dataset

Then, the researchers calculated the below values to each historical data, based on the required inputs to the simulation model:

GROUP A	Taxi Fuel	Mean = 168.78	S.Dev = 78.05	-
	Planned Trip Fuel	Mean = 2116.86	S.Dev. = 341.04	-
	Alternate Fuel	Mean = 1776.39	S.Dev. = 415.72	-
	Extra Fuel	Mean = 732.03	S.Dev. = 577.08	Local = 0.00
	Holding Fuel	Mean = 1000.14	S. Dev = 65.96	-
	Cons. Factor	Mean = 0.97	Scale = 0.05	-
GROUP B	Taxi Fuel	Mean = 155.48	S.Dev = 74.44	-
	Planned Trip Fuel	Mean = 3702.50	S.Dev. = 718.20	-
	Alternate Fuel	Mean = 1929.97	S.Dev. = 502.12	-
	Extra Fuel	Mean = 677.46	S.Dev. = 543.14	Local = 0.00
	Holding Fuel	Midpoint = 1024.80	Scale = 73.59	Deg.Freed. = 10.38
	Cons. Factor	Mean = 0.97	Scale = 0.03	-
GROUP C	Taxi Fuel	Mean = 151.83	S.Dev = 91.10	-
	Planned Trip Fuel	Mean = 6549.93	S.Dev. = 985.83	-
	Alternate Fuel	Mean = 1853.11	S.Dev. = 556.35	-
	Extra Fuel	Mean = 625.69	S.Dev. = 453.03	Local = 0.00
	Holding Fuel	Mean = 1136.14	Scale = 64.47	-
	Cons. Factor	Mean = 0.99	Scale = 0.03	-
GROUP D	Taxi Fuel	Mean = 155.51	S.Dev = 129.67	-
	Planned Trip Fuel	Mean = 8833.71	S.Dev. = 1560.57	-
	Alternate Fuel	Mean = 2071.83	S.Dev. = 578.42	-
	Extra Fuel	Mean = 641.60	S.Dev. = 360.54	Local = 0.00
	Holding Fuel	Mean = 1231.79	S.Dev. = 171.95	Local = 804.39
	Cons. Factor	Mean = 1.00	Scale = 0.02	-

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GROUP E	Taxi Fuel	Mean = 261.04	S.Dev = 212.17	-
	Planned Trip Fuel	Mean = 13319.29	S.Dev. = 4771.42	-
	Alternate Fuel	Mean = 2607.19	S.Dev. = 670.40	-
	Extra Fuel	Mean = 612.00	S.Dev. = 342.72	Local = 0.00
	Holding Fuel	Mean = 1463.58	S.Dev. = 381.58	Local = 828.73
	Cons. Factor	Mean = 0.98	Scale = 0.02	-
GROUP F	Taxi Fuel	Mean = 730.16	S.Dev = 469.23	-
	Planned Trip Fuel	Mean = 73339.41	S.Dev. = 44266.92	-
	Alternate Fuel	Mean = 1825.96	S.Dev. = 655.44	-
	Extra Fuel	Mean = 1091.03	S.Dev. = 885.71	Local = 0.00
	Holding Fuel	Mean = 5170.53	Scale = 700.00	-
	Cons. Factor	Midpoint = 0.93	Scale = 0.02	Deg.Freed. = 9
GROUP G	Taxi Fuel	Mean = 845.42	S.Dev. = 273.26	-
	Planned Trip Fuel	Mean = 82164.67	S.Dev. = 12514.43	-
	Alternate Fuel	Mean = 2195.25	S.Dev. = 776.54	-
	Extra Fuel	Mean = 80.84	S.Dev. = 156.31	Local = 0.00
	Holding Fuel	Midpoint = 7694.41	Scale = 850.00	Deg.Freed. = 1
	Cons. Factor	Midpoint = 0.98	Scale = 0.02	Deg.Freed. = 11

Table 5 – Inputs for simulation model calculated from historical observations

With the above values inputted into the mathematic model, the researchers simulated 200,000 flights for each of groups A, B, and C, and 50,000 flights for groups D, E, F, and G, totalizing 800,000 flights simulated to find the remaining fuel.

The results are shown in Figures 7 to 13, which provides the frequency of remaining fuel values, and reveal the pattern of a Normal distribution for all simulations groups.

From each graph, we observe the average value and standard deviation. Following the Empirical Rule, the parameters of mean and standard deviation can be used to define the population covered by the results of a Normal Distribution, where two values of standard deviations result in coverage of 95,4% of the results (edX,2019).

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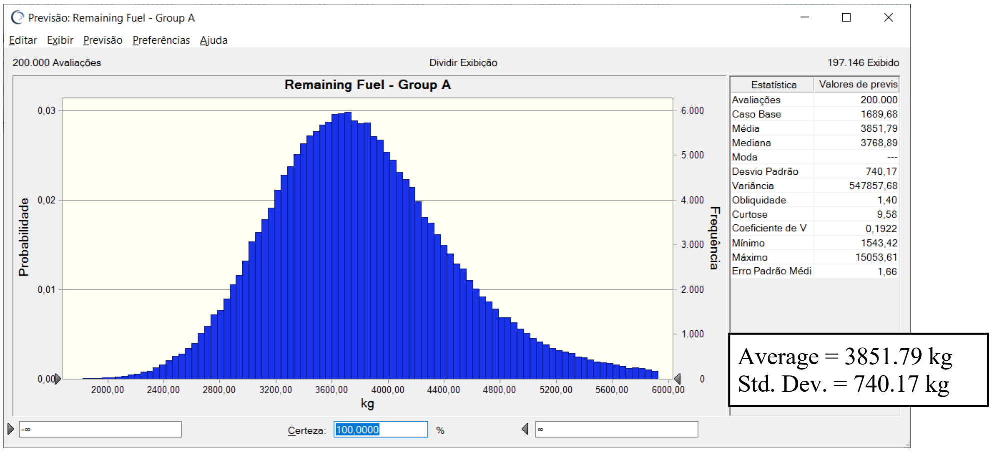

Figure 7 – Probability distribution of remaining fuel on Group A simulation

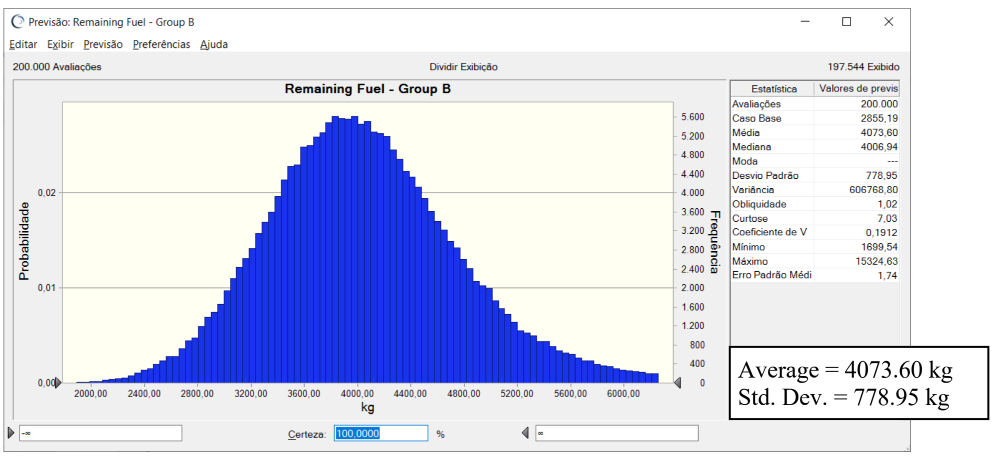

Figure 8 – Probability distribution of remaining fuel on Group B simulation

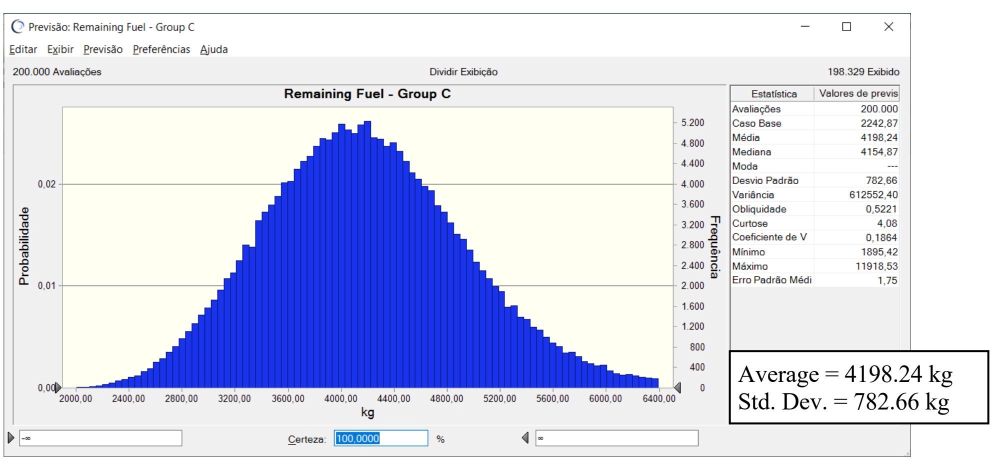

Figure 9 – Probability distribution of remaining fuel on Group C simulation

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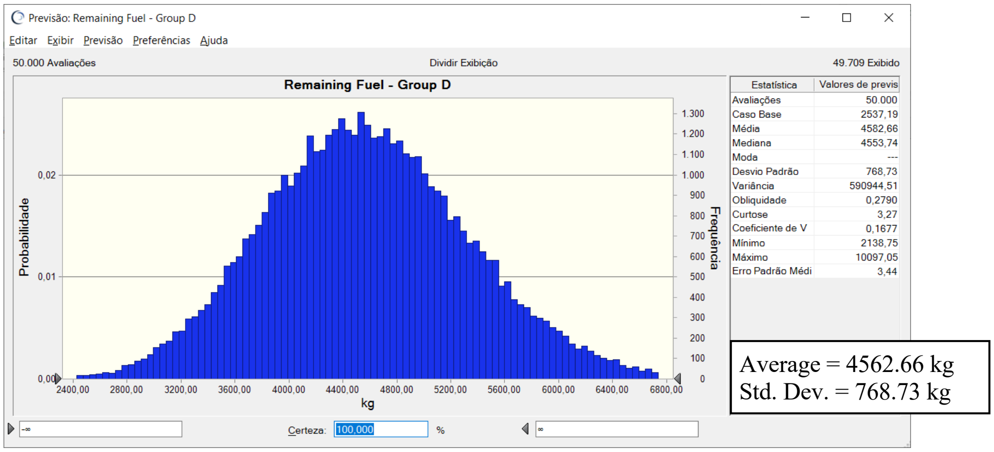

Figure 10 – Probability distribution of remaining fuel on Group D simulation

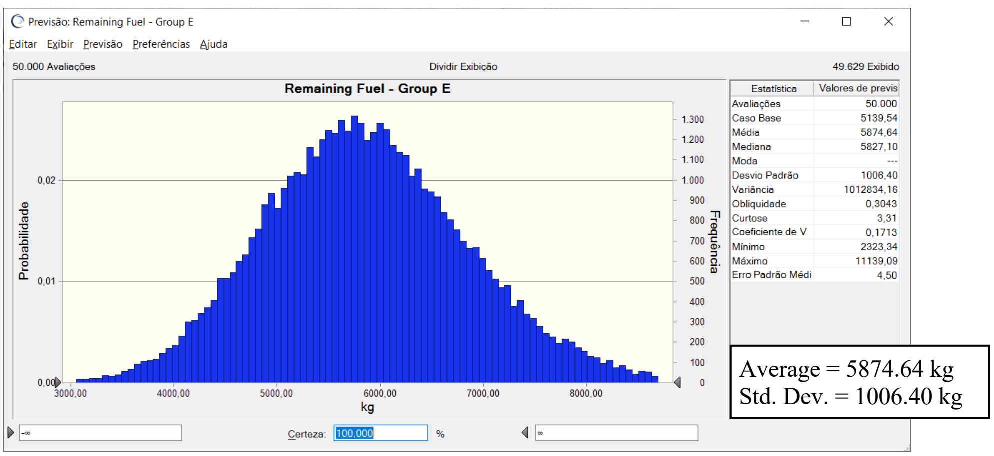

Figure 11 – Probability distribution of remaining fuel on Group E simulation

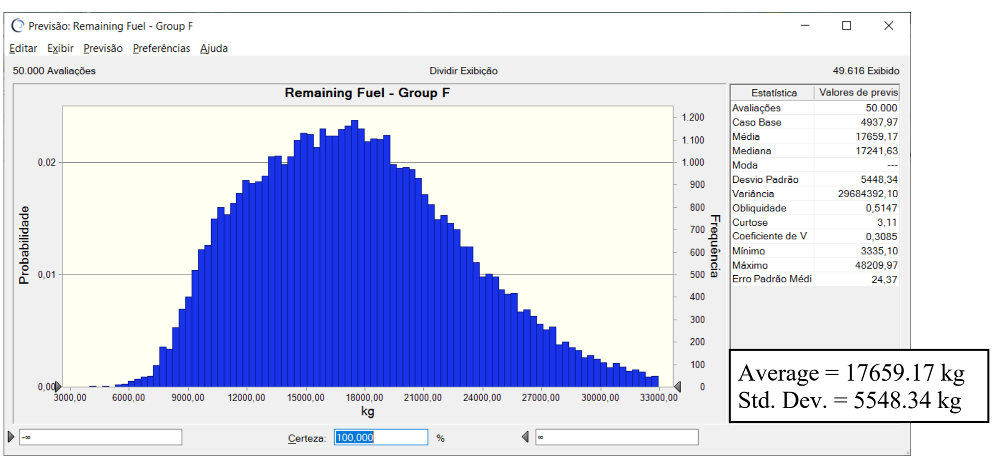

Figure 12 – Probability distribution of remaining fuel on Group F simulation

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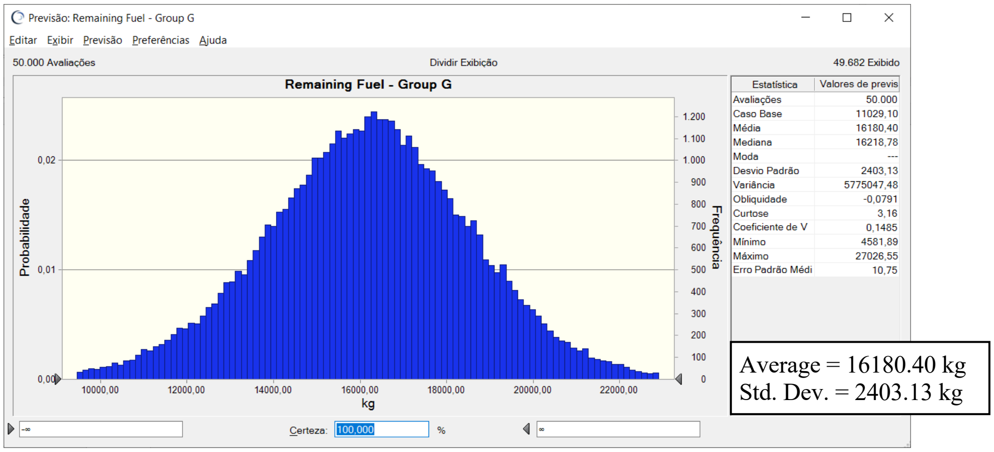

Figure 13 – Probability distribution of remaining fuel on Group G simulation

Then, applying (adding and subtracting) two values of standard deviations over the average value of the remaining fuel of each simulation, the researchers built the below table that confirms that any flight would have the following maximum and minimum remaining fuel, with 95,4% of probability.

	Average Remaining Fuel	Minimum Remaining Fuel	Maximum Remaining Fuel
Group A	3851 kg	2371 kg	5331 kg
Group B	2855 kg	1297 kg	4413 kg
Group C	2242 kg	677 kg	3807 kg
Group D	4582 kg	3045 kg	6119 kg
Group E	5874 kg	3861 kg	7887 kg
Group F	17659 kg	6762 kg	28556 kg
Group G	16180 kg	11364 kg	20996 kg

Table 6 – Range of remaining fuel value with 95,4% of probability

Data coming from each simulated flight were also assessed and analyzed separately to compare the remaining fuel and the minimum reserve fuel (holding fuel). The researchers also evaluated if any flight “landed” with less remaining fuel than the

Case Study: Contingency fuel reduction

minimum required, or in other words, in an emergency condition. Table 7 presents the resume of simulation results and the comparison between remaining fuel and minimum reserve fuel.

	Flights simulated	Smallest Remaining Fuel	Smallest difference to the reserve fuel
Group A	200,000	1543 kg	+ 559.90 kg
Group B	200,000	1699 kg	+ 676.52 kg
Group C	200,000	1895 kg	+ 847.64 kg
Group D	50,000	2138 kg	+ 996.39 kg
Group E	50,000	2323 kg	+ 731.63 kg
Group F	50,000	3335 kg	+ 280.16 kg
Group G	50,000	4581 kg	+ 47.18 kg

Table 7 – Results of simulations for remaining fuel and difference to reserve fuel

Our study shows in the last column of Table 7 that, after 800.000 simulations using historical data. No flight would land below minimum reserve fuel (holding fuel) after contingency fuel was changed to 5% of the Trip Fuel.

Summary

As a result of the change in the contingency fuel regulation, from the existing 10% of the trip time to the new 5% of trip fuel, it is possible to observe a potential saving of approximately 0,2% on airlines annual fuel budget, due to the lower quantity of fuel burn to carry unnecessary fuel.

Table 8 resumes the potential savings of this change:

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	AIRLINE A	AIRLINE B
TOTAL DIF (kg)	-2,368,347	-3,106,603
TOTAL DIF (L)	-2,960,433	-3,883,254
FUEL COST (R$/L)	2.91	2.91
DESNTIY (kg/L)	0.8	0.8
SAVING (R$)	-8,614,860.70	-11,300,268.66
DOLLAR CONVERSION	4.15	4.15
SAVING (US$)	-2,075,870.05	-2,722,956.30
FUEL BUDGET US$	998,317,000	1,298,536,960
% SAVINGS	**-0.21%**	**-0.21%**

Table 8 – Potential savings after contingency fuel reductions

The outcomes from both statistical and simulated studies confirm that the proposed contingency fuel percentage reduction would not affect the safety level of operations. By analyzing the results, there is enough evidence to support that no flight would land with a fuel quantity lower than the minimum reserve due to the legislation change.

The statistical study also shows that when changing the contingency fuel from 10% to 5%, 29% of flights would experience an increase of fuel after landing. This observation disproves the general thinking that by reducing the contingency fuel, we would see a simple linear reduction of the amount of fuel available to the pilot in the most critical moment for their decision-making process, approach, and landing.

The simulation ran in this project, using random entries within 800,000 fuel consumption calculations in different flight categories. The results demonstrate that the remaining fuel in the aircraft flying in the new rules has its minimum value above the minimum required reserve fuel. In other words, the results demonstrate that no flight would enter the fuel emergency condition.

Chapter V

Overview of the research

The purpose of the study was to scientifically support a change in the Brazilian aviation rules regarding the reduction of the required contingency fuel from 10% to 5%.

ABEAR requested this change to ANAC to increase Brazilian airline competitiveness in the global aviation market since other International authorities have already changed their rules in this direction.

Our study aimed to analyze real flight data and also simulate thousands of random flights using the new contingency fuel percentage to assure that the change could be made without jeopardizing flight safety.

Summary of results

The researchers divided this study into two separates analysis. The first one looked at a group of over two hundred and ninety thousand flights from two of the largest Brazilian Airlines. The researchers used planning data and also real flight data to be able to further understand if the proposed change in the fuel calculation method, would impact the remaining fuel amount after landing. By doing that, we were able to evaluate if there will be a decrease in Flight Safety if the regulation change is approved.

The result showed, with a confidence interval of 99,92%, that 71% of flights had the fuel on landing reduced when compared with the current regulation. And surprisingly, the remaining 29% of flights had an increase in their fuel quantity on landing.

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However, the information we were looking for is to find out if any flight has arrived on the ground after landing with a fuel amount less them the regulatory minimum, which would put it into a fuel emergency condition.

The final result was that only one flight amongst over almost three hundred thousand has landed in a fuel emergency condition. However, the researchers decided not to consider this information to be valid since it has arrived in an emergency fuel condition even under the actual fuel regulatory rules, meaning even having the 10% fuel contingency fuel available.

The second part of the study was to randomly simulate thousands of flights, using the Monte Carlo simulation, to see if it would point to similar results of the first study.

After using random entries within 800,000 fuel consumption values, the simulation statistically demonstrated that no flight entered the fuel emergency condition, reinforcing the same conclusion achieved in the first study.

By having both studies getting the same conclusion, we are now able to scientifically support that the change in the Brazilian fuel regulation can be made without decreasing our Flight Safety.

All results were sent to ABEAR to be presented to ANAC together with the fuel data from all major Brazilian airlines.

All these documents were presented to ANAC to technically support the regulatory change that could lead to a US$ 6.5M per year in fuel savings for Brazilian Aviation, considering 0,21% of the current fuel budget of the three biggest airlines flying in Brazil.

Case Study: Contingency fuel reduction

Limitations of the study

The first limitation was the availability of flight data fuel records. The researchers were only able to get data from two of the three major Brazilian Airlines. Although it was sufficiently representative and it would be better if this project had been supplied with the material from the third airline.

Another important limitation was the availability of free software to develop the simulations. Although the researchers have positive and reliable results using the Monte Carlo simulation application and believe that would enrichen the study to have used aviation-related software such as AMADEUS, SABRE, or JEPPESEN.

Other studies related to impacts in-flight operations use to also analyze data by applying seasonality effects. This project did not have additional data (more than one year) to evaluate the effects of the seasonality on fuel planning and consumption. However, the researchers understand that the evaluation of each single flight separately was sufficient to achieve the project objective.

Information gained from the study

The researchers believe our study is the only one available on this matter that have used simulation and also that took into account the statistical value of the data studied. The Airlines only gave ABEAR a mathematical study, not guaranteeing a specific significance interval. The quality and significance of our data should help convince those who have doubts about the maintenance of the Flight Safety values.

Case Study: Contingency fuel reduction

Conceptual Implications

This study supports that all countries that have already made this change in fuel calculation policies were right when they took this decision and that Brazilian Authorities should head in the same way.

This study also can solve any doubts the reader should have of the feasibility of this change regarding fuel management safety.

Future implications

This study took into consideration a mathematical and statistical view of the proposed regulatory change. The researchers believe that this is only one part of the impact it will have on Brazilian Aviation.

The researchers think that further studies should cover how flight dispatchers and pilots will react to the reduction of the contingency fuel percentage.

One possible outcome is that pilots and flight dispatchers would increase the amount of extra fuel personally added to the flight plan since they are not used to the new regulation.

This could lead to a decrease in the fuel cost reduction, and depending on how strongly they react, it could also lead to an increase in fuel costs in comparison with the actual fuel figures.

The researchers believe that Airlines should take care of the implementation process, making it clear to all stakeholders that the Safety levels will be maintained and that there is no new reason that should lead to an increase in extra fuel requests.

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