The Impact of Unscheduled Maintenance to an Airline's on Time Performance

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

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Abstract

Group: E – CA-MEL

Title: The impact of Crew Applied MEL to an Airline's On Time Performance

Institution: Embry-Riddle Aeronautical University – Worldwide Campus

Year: 2021

Unscheduled maintenance events have a significant impact on airlines performance and network operations. Some events can have its consequences minimized by simple actions due to its simplicity and lack of influence in the safe conduction of a flight.

This study aimed on collecting data regarding the cost and consequences of ground turn back events in the Airbus A320 family. The study suggested that after the implementation of proper supporting regulation on Crew Applied MEL, money would be saved as well as network disruption consequences could be avoided.

The data presented in this study reflects current Brazilian legislation, and data from reliability engineering, targeting to present the overall impact of Gate Returns during the taxi-out phase.

The research presented an estimated combined savings of U$1.239.833, coming from 14.769 minutes and 221 flight delays that could have been avoided in a five-year period (2016-2021).

Crew Applied MEL procedures are widely known worldwide but lacks on supportive regulations in Brazil. Therefore, this study also found an opportunity to regulations improvement in order to allow airlines to implement Crew Applied MEL.

Table of Contents

List of Tables

Page

Table

List of Figures

Page

Figure

Chapter I

Introduction

Airlines use their own performance measures to evaluate the impact of their decisions. It is very crucial to understand these measures and interpret their meaning. These performance measures are easy to understand when compared across airlines or when compared against historical values (Abdelghany, A. & Abdelghany, K. 2018).

On-Time Performance (OTP) is a widely accepted method of understanding punctuality for different modes of public transport, including aviation. It provides a standardised means of comparing how well one service provider operates according to its published schedule compared to another (OAG, 2020).

Managing On Time Performances and gate returns caused by unscheduled maintenance are great ways to improve operational efficiency among airlines. After identifying the need to return to gates to solve all minor malfunctions, research has identified that Brazilian regulations lack the ability to allow flight crews to judge and act on minor maintenance situations, Crews based on their experiences, knowledge of manuals, and with the support of maintenance control centers, should be able torelease the aircrafts for flight under MEL rules.

Opportunities to reduce flight delays due to minor maintenance situations have also been found by allowing operations personell in airports where there is no available mechanics to release aircrafts. Such locations are very common due to Brazil's geography characteristic,s.

On Time Performance is an important factor to Brazilian airlines. It dictates the capability to operate at certain busy airports in the country. These are the airports where

the most profitable routes depart and arrive, every day. This OTP index is affected by many factors that may cause a flight delay. One of the key factors is the unscheduled maintenance.

Unscheduled maintenance procedures can happen at any time and anywhere. As aircraft are becoming increasingly more electronic and self monitored, systems are also becoming more sensitive to failures. Those malfunctions can be present before the doors are closed. With such issues a maintenance mechanic would come onboard and check for the system operationality and dispatch conditions. Its an airline's decision, taken among pilots, mechanics, and the Maintenance Control Center (MCC), to decide if an airplane will be dispatched with a system considered inoperative or if maintenance actions will be taken at that time. This decision is based in the airline's best interest. Criteria for such decisions can be found in a list called MEL – Minimum Equipment List. The list states all of the minimum required equipment for a flight to take place.

As part of the airworthiness requirements, an aircraft cannot be dispatched with an inoperative equipment or system unless this is allowed by the Minimum Equipment List (MEL) under any applicable conditions (Obadimu, S. O., Karanikas, N., & Kourousis, K. I. 2020). The MEL is designed by the airlines, according tho a M-MEL, Master-Minimum Equipment List. The last of which is designed by the manufacturer to assure minimum system operationality. The rationale is to allow the safe operation of the flight by applying certain conditions stated in the manual. The airline can build its own MEL following the implementation of a new aircraft model. This list can be more restrictive than the M-MEL. It is usually designed based on the operations profile of the airline. The MEL is subject to local authorities' approval.

If a system is deemed to be dispatched inoperative, different outcomes may arise. There might be maintenance procedures to be performed by mechanics. There may also be operational procedures, which would be performed by the pilots and flight dispatchers at the OCC (Operational Control Center). The purpose here is to make all required adjustments to that flight comply with the procedures required in the MEL. All of the different procedures are stated in different chapters of an MEL.

Problem Statement

The impact of unscheduled maintenance to the OTP is critical. Some actions can be postponed to the next opportunity to perform scheduled maintenance, as they have no impact on the safe operation of the flight. In situations where adequate procedures can be taken, the corrective actions will be completed. This research project aims on comparing current legislation from other countries in order to build a Brazilian version, adapted to our reality. There is a great number of dispatchable malfunctions that do not require maintenance procedures. These steps could be easily done by the pilots on the taxiways, with brief stops in the taxi procedures.

A return to the gate may end in the need to resend the flight plan to air traffic controllers. In addition, there may be a need to return to the line again for departure. Such actions could take at least 45 minutes according to the regulations.

For this study, focus has been given to the Airbus A320 fleet, widely used by major Brazilian airlines and, also, worldwide.

Current regulations in Brazil require qn aircraft to return to a gate, if a malfunction is detected before take off. Pilots must turn back to the gateand open doors. Maintenance procedures will need to be conducted in the presence of a maintenance

mechanic. Another loss that can not be properly measured is that one related to the airline image and marketing. Passengers often get aggravated and nervous when a malfunction happens to their aircraft.

The self dispatch of those small malfunctions is a common practice in the industry in other countries. It could be explored deeper in Brazil, as well as being compared with procedures used in both the the U.S. and Europe.

After compiling all regulations available at FAA's and EASA's websites, a benchmark with the Brazilian regulations will be made to look for improvement gaps. The assessment of all self dispatchable procedures will also be provided. Finally, the study will separate those delays by causing agent (determined by the airline). A comparison will be made of the findings in the MEL research to figure out how many of those delays could have been avoided or decreased. A safety matrix will also be provided to show the probability and severity of a few of the most common issues. The intent is to show that most of them could be dispatched inoperative by the pilots with no prejudice to the safety of the flight.

Project Definition

Several areas of the commercial aviation could take advantage of this research. At the center of this research will be airlines and regulatory agencies. With an optimized OTP index, airline's network planning personnel could apply for more slots in the involved airports, thus increasing the profit and the optimization of an airline's network.

Airbus, through its publication called "Safety First", addresses that specific situation. The report atates that different procedures may be applied by different regulatory agencies around the world. This study will collect the most relevant

information about that subject and build a new proposal of regulations for Brazil's Agência Nacional de Aviação Civil (ANAC).

Project Goals and Scope

The basic principle of this study is to identify and implement new and updated regulation regarding the dispatch of aircraft with malfunctioning systems performed by the pilots.

The study is aware that pilots do not perform any MEL dispatch, as it is an airline's Maintenance Control Center's duty. Therefore, through modern communication techniques, widely applied in today's aviation, such as SATCOM, ACARS and, lately, onboard Wi-Fi connectivity, pilots can easily reach out to ground stations and get advice from maintenance personnel. Those will carry the final responsibility for releasing that inoperative system for flight. A system write-up to the maintenance software will also be performed to keep track of the malfunction and its due date. Inoperative systems may have different deadlines to be solved, according to its complexity and importance.

Contributions Expected from the Study/Importance of Topic

A major contribution expected from this study is the time saving in the flight release of aircraft following minor malfunctions. Research will provide the opportunity to expand an airline's network not depending on mechanics being employed in the destination, without jeopardizing the safety of the operations. The study will demonstrate a proposal to the local authorities in Brazil. The intent here is to build a new regulation in conjunction with the airlines. This regulation is to allow corrective action to be taken by pilots without the need of a mechanic.

Research Questions

With this new regulation implemented, and full acknowledgement of the Brazilian Civil Aviation Authority, this research project plans to improve airline's On Time Performance. In addition, such improvements would allow for better accessability of the slot availability at some monitored airports in Brazil. To do so, we plan to answer the following question:

1. How useful can be a self-dispatch procedure following a system malfunction after doors have been closed?
2. How can airlines establish those procedures in order to not jeopardize the safe conduction of the flight, fulfilling all MEL requirements?
3. How extensive is the impact of unscheduled maintenance in the OTP?

Definitions of Terms

A320	Airbus A320, aircraft model manufactured by Airbus Industrie
OTP	Index that measures the capability of an airline to depart flights on time.
Dispatch	Release aircraft for flight, fulfilling all documentation requirements.
Gate Return	The need of an aircraft to return to gate after taxi out phase has been commenced.
Inoperative	Some items have been designed to be fault tolerant and are monitored by computers which transmit fault messages for maintenance purposals. The presence of this category of message does not necessarily mean that the item is inoperative.

List of Acronyms

ACARS	Aircraft Communication Addressing and Reporting System
AHM	Airport Handling Manual
ANAC	Agencia Nacional de Aviação Civil – Brazilian Civil Aviation Authority
APU	Auxiliar Power Unit
COVID-19	Disease caused by Coronavirus
DDG	Dispatch deviation guides
DDPG	Dispatch deviation procedures guides
EASA	European Airspace Safety Agency
EU	European Union
FAA	Federal Aviation Administration
GTB	Ground Turn Back
IS	Instrução Suplementar
MGOA	Manual Geral de Operações Azul
MCC	Maintenance Control Center
MEL	Minimum Equipment List
M-MEL	Master-Minimum Equipment List
OCC	Operations Control Center
OTP	On Time Performance
RBAC	Regulamentos Brasileiros da Aviação Civil - Brazilian Civil Aviation Regulations
USA	United States of America

VHF Very High Frequency Radio

Plan of Study

To the completion of this project, we plan to bring the attention to the following topics, to be covered in the next chapters:

- Chapter Two - **Literature Review**, where the study plans to compile the literature from regulators around the world where this practice has been supported and benchmark them with the Brazilian current regulations. Research will also compare the MEL and M-MEL available to collect data regarding the number of malfunctions that do not require maintenance or operational actions to be taken. Those will be the focal point of our research.
- Chapter Three - **Research Methodology**, where research plans to:
    - appraise the impact of gate returns in the OTP of an airline,
    - assess the operational impact of expanding the network to a base where there will be no available mechanics,
    - describe a safety matrix,
    - expalin the safeness of the proposed new regulations. In this part, data regarding the delays caused by mechanical malfunctions and flight interruptions will be displayed.
- Chapter Four- **Outcomes**, where research will display the overall impact and the possible reduction of this impact in the OTP of an airline. As a result airlines will enlarge their network, thus not needing to hire more workforce. In this chapter, data presented will support the creation of new regulations, thus allowing this practice to become more common among Brazilian commercial airlines.

- Chapter Five- **Conclusions, Recommendations, and Lessons Learned**, where the outcomes research will point to a direction, allowing or recommending the airlines to follow new regulations and new operational procedures. This conclusion could lead Brazilian commercial airlines to improve their operations. In this chapter, the conclusion will show how significant is the impact of the unscheduled maintenance to an airline's on time performance (OTP).

Chapter II

Review of the Relevant Literature

Airlines currently use several different systems to report delays. Some use IATA standards, reporting relevant information about a delayed flight. Keeping this record is important to measure the impact of delayed flights to the network and to its passengers (Sarseshiki et al., 2010). The total delay time is directly related to an airline's On Time Performance (OTP). This index must be kept in the higher levels possible, without jeopardizing safety. Some researchers have already tried to enhance the delay code assignment table in order to develop beter data mining and analytics (Wu, et al., 2014).

Aircraft operability is considered a major requirement by each airline operator. The occurrence of unscheduled maintenance can introduce costly delays and cancellations if the problem cannot be rectified in a timely manner. (Papakostas, et al., 2010). The operability of an aircraft is defined as how does the aircraft meet the operational requirements, to perform scheduled flights without incurring any delay to attend unscheduled maintenance needs. Those procedures may add significant costs to the aircraft operation. The trade-off is very complex and priorities may vary a lot depending on the airline's policy (Papalostas, et al., 2010). Those priorities are also subject to local authorities approval.

Different flight stages determine the severity and need to return to the gate (if still taxiing out) or origin airport (if airborne). Contingencies may happen at any moment after an aircraft has started moving after boarding is complete.

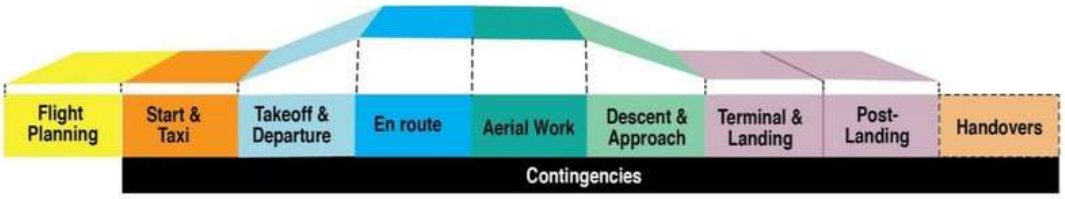


Figure 1: Flight phases description

Brazilian airlines are required to follow ANAC's resolution 218 to send monthly the list and reasons for all flights that have been canceled or delayed. The reasons for flight delays are defined by the International Air Transport Association (IATA), in AHM 730 through codes, which are called Delay Codes.

In this research, we aim on looking at some very specific two letter delay codes, as they might represent delays that could have been avoided if the flight crew could evaluate the situation in coordination with the OCC and proceed with the flight with no additional risks being added. These codes are for unplanned reasons and cover the events which create an Operational Interruption.

Master Minimum Equipment List Purpose

The MMEL is a document that lists the items which may be temporarily inoperative, associated with special operating conditions, limitations or procedures, as applicable, for a specific aircraft type or model. An MMEL document may cover more

than one aircraft type provided that benefits on commonality can be taken and the applicability of each item is clearly indicated.

In this research, the Airbus MMEL is a dispatch document that is produced by the aircraft manufacturer and approved by the certification authorities.

The MMEL was used as a reference by the operators under study - LATAM Airlines and Azul Linhas Aéreas Brasileiras - to create their own MEL, which allows the dispatch and operation of an aircraft with one or more operational equipment or unavailable system while maintaining an acceptable level of safety.

Each MMEL contains the following:

(1) Approval status, including date of approval and effective date.

(2) A preamble, containing considerations on the purpose and limitations, utilisation, multiple inoperative items, rectification interval extension, definitions and, if

appropriate, clarifying notes which adequately reflect the scope, extent and purpose of the list.

(3) The list of items, including for each item:

- the rectification interval category;
- the number installed or a dash symbol, as applicable;
- the number required or a dash symbol, as applicable;
- the operational procedure symbol, as applicable;
- the maintenance procedure symbol as applicable;
- placarding indications, as applicable; and
- any associated conditions and limitations, including the intent and periodicity for the accomplishment of the operational and maintenance procedure, as applicable.

Where there is a requirement for a specific maintenance procedure, then an (M) symbol should be included as part of the MMEL entry to indicate this. Where there is a requirement for a specific operational procedure, then an (O) symbol should be included as part of the MMEL entry to indicate this.

A decision on whether the necessary procedure can be assigned as an (O) or an (M) should be based on which is the most appropriately qualified trade to carry out the procedure and which trade would normally carry out such a task in their line of duty, based on the intended types of operation normally performed by the aircraft. On this basis

deactivation and securing tasks should normally be assigned an (M) while procedures based on operation of equipment should normally be assigned an (O).

According to current regulatory background, airlines have established procedures for troubleshooting after a malfunction is presented on ground. This is depicted in the

"Ground Troubleshooting Flow", placed in the aircraft's QRH (Quick Reference Handbook). Note that there is no mention to the applicability of CA-MEL.

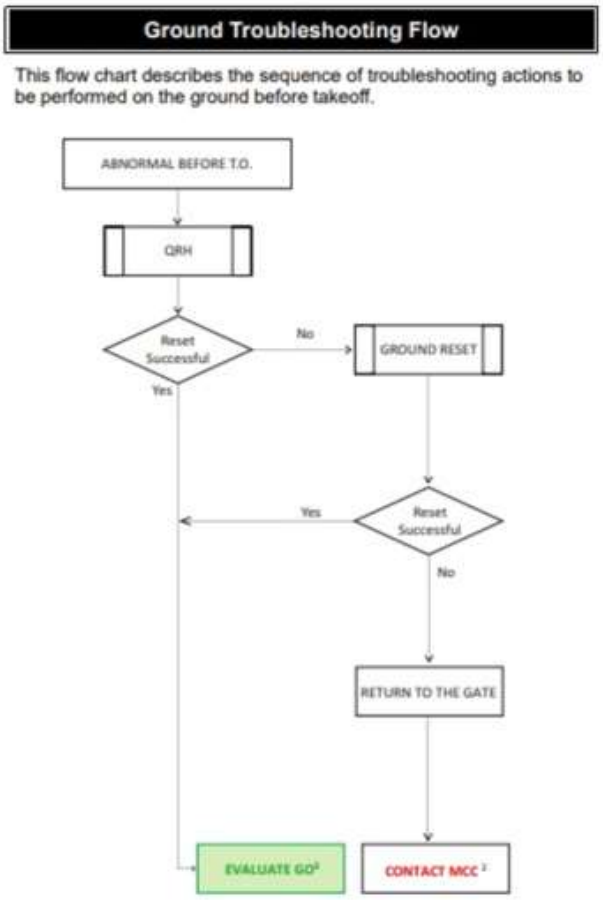
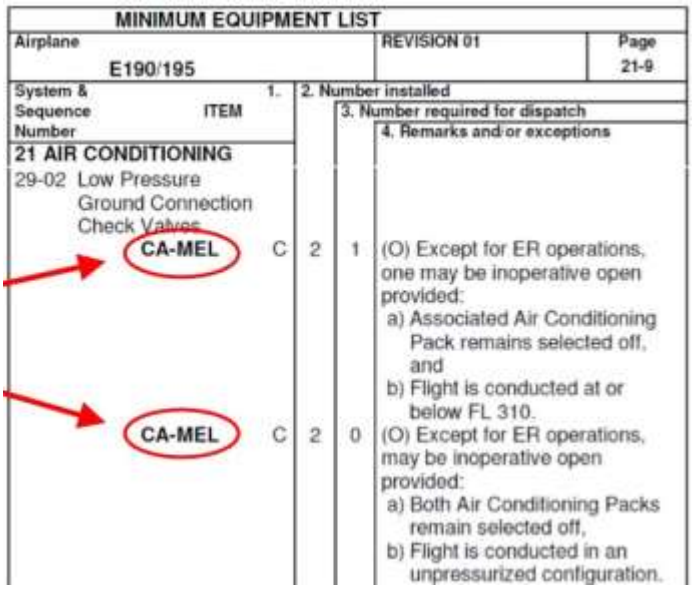


Figure 2: Ground Troubleshooting Flow

Crew Applied MEL Definition

Crew Applied MEL, or simply CA-MEL, is denominated for items whose TLB differ and aircraft release could be done by the captain, without the need of the presence of a mechanic. Such items are identified as CA-MEL in the MEL of that specific fleet (Azul Linhas Aéreas MGOA, 2019).



MINIMUM EQUIPMENT LIST

Airplane E190/195				REVISION 01	Page 21-9
System & Sequence Number	1. ITEM	2. Number installed	3. Number required for dispatch	4. Remarks and/or exceptions	
21 AIR CONDITIONING					
29-02 Low Pressure Ground Connection Check Valves					
	CA-MEL	C	2	1	(O) Except for ER operations, one may be inoperative open provided: a) Associated Air Conditioning Pack remains selected off, and b) Flight is conducted at or below FL 310.
	CA-MEL	C	2	0	(O) Except for ER operations, may be inoperative open provided: a) Both Air Conditioning Packs remain selected off, b) Flight is conducted in an unpressurized configuration.

Figure 3: Minimum Equipment List – CA-MEL example

The Manual Geral de Operações Azul (MGOA) also mentions the situations when CA-MEL release could be applicable:

1. Discrepancies found during aircraft transit and when the mechanic is not available;

2. Discrepancies that occur during or after the “push back”, before the “take off”;

3. Discrepancies found in route and reported to the destiny base where the mechanic is not available.

MEL Application according to EASA

EASA regulations state that the captain may decide to continue with the flight based on “good judgment and airmanship” (Airbus, 2018). The flight crew might

communicate with dispatch, or the MCC, therefore the final decision to continue with the flight is the responsibility of the captain, but taken in coordination with maintenance teams (Airbus, 2018).

MEL application according to FAA

FAA regulations state that the captain must communicate with dispatch and MCC in order to determine if the aircraft can be dispatched. Certain MEL procedures may be accomplished by the flight crew without returning to the gate (Airbus, 2018).

MEL application according to ANAC

ANAC states that it is the pilot in command or a flight dispatcher assigned by the airline the responsible for releasing a flight, after making sure that all safety requirements are met.

Airbus estabilishes those procedures and enables the crew to dispatch the aircraft with inoperative items after doors have been closed, as long as local authorities certify that practice for the airline. In Brazil, no Airbus A320 operators use CA-MEL due to lack of certification by local authorities.

Air Transport Aircraft with Brazilian Registration

Every airline in the world, as part of the requirements for its certification, has the obligation to prepare the Maintenance Program, have it approved by the civil aviation authority and properly apply, or comply with the minimum requirements imposed by the aircraft and parts manufacturers as well as by the aviation authorities of the country of origin of the plane.

In Brazil, the guideline is the same, but we have to take into account that each company has its operational characteristics. Although all are governed by the same

Brazilian regulations and are based on documents issued by the aeronautical manufacturers and authorities of origin of their aircraft, each one ends up using their Maintenance Programs in a distinct way, though approved by the local regulatory agency, ANAC (National Civil Aviation Agency).

Regulatory Documents

The MEL is mandatory for any aircraft operating under the rules of RBAC 121. In section 628 of this RBAC, it is established that each operator must make available in its manual set the MEL for each type of aircraft in the fleet, which is approved by ANAC. Thereafter, the MEL will inform whether the aircraft will be released to fly without some instrument, equipment or system operating normally is authorized or not.

As established by the FAA, the MEL is based on the MMEL, and its revisions applicable to the aircraft type. It is prepared by the operator and must be approved by the Aeronautical Authority of the country in which the aircraft is registered and operating.

The MEL aims to help the captain to make the decision to proceed or not with the operation of the aircraft. It is important to emphasize that the MEL is only related to the release to flight with inoperative systems. If there are further failures, the AFM (Aircraft Flight Manual) must be applied to proceed or not with the operation. Therefore, RBAC 121 also stablish that the responsibility for dispatching an aircraft in safe conditions rests with both the Captain and the Flight Operational Dispatcher.

Currently, ANAC has been working on a SUPPLEMENTARY INSTRUCTION , not published yet, which aims to present a methodology that guides for the preparation of a Minimum Equipment List (MEL) acceptable by ANAC, capable of allowing the operation of aircraft with certain equipment or instruments inoperative, under certain

conditions and limitations in order to comply with the requirements of sections 121.628 of RBAC No. 121, as well as other sections that require or allow the preparation of MEL by the operators.

In this IS, the Procedures (O) and (M), focus of our study, are detailed. When required by the MMEL, the MEL must contain the operational (O) and maintenance (M) procedures, containing the step-by-step necessary to ensure the safety of operations with an inoperative item.

Procedures (O) and (M) defined by ANAC

The development of these procedures is the responsibility of the operator, who must prepare them based on the guidelines described in the MMEL, the procedures recommended by the manufacturer (such as Dispatch deviation procedures guides - DDPG or Dispatch deviation guides - DDG, when they exist) and in other technical publications manufacturer, always in accordance with their latest revisions.

The operator must indicate the references used to develop its procedures, including part number, the revision number and date of these reference publications (eg maintenance programs, maintenance manual, service manual, DDPG, DDG, among others).

Note: some MMELs have a “Guidelines for (O) & (M) procedures” section. Usually, these guidelines are not equivalent to procedures, as they do not clearly indicate what actions should be taken, but only their objectives. In such cases, the operator should consider these guidelines, together with other applicable technical publications, to develop its procedures

Finally, ANAC identified an opportunity for improvement in the regulation and mentioned the Crew Applied MEL (CA MEL). In the IS (Instrução Suplementar – Supplementary Instruction), it is mentioned that in some MMELs or related procedures (DDPG or DDG), the concept of "Crew Applied MEL" is used, which would identify the procedures that could be performed by the pilots. However, such procedures, when including procedures (M), can only be performed and approved for release to service by an authorized person according to sections RBAC 43.3 (Persons authorized to perform maintenance, preventive maintenance, rebuilding, and alterations) and RBAC 43.7 (Persons authorized to approve aircraft, airframes, aircraft engines, propellers, appliances, or component parts for return to service after maintenance).

Summary

Several different regulations issued by aviation authorities from different countries state different rules and procedures regarding the dispatch of an aircraft made by pilots if a malfunction is detected after doors have been closed. In Brazil, ANAC sees this possibility as feasible, identified opportunities for improvement in the interpretation of the requirement, started to develop a draft, but there is not enough supporting regulation or background to determine if this procedures can be performed in different fleets. Airbus A320 family, one of the widest utilized aircraft in Brazil, for example, does not have procedures specified.

This research plans to bring to light some numbers regarding delayed flights which those malfunctions could have been solved by flight crews, cutting the need for return.

Nowadays, there are plenty of different ways to reach the MCC, leaving the VHF phone patch as a first option, but not limiting to it. There is ACARS, onboad Wi-Fi and good cell phone coverage available at most of the airports in Brazil.

The impact of delays can be very costful to airlines, jeopardizing the capability to request for more slots at some airports. Another important factor, that can hardly be measured is the impact on the image of the airline and the stress added to passengers after a gate return is needed, and maintenance crew comes aboard.

“The bitterness of poor quality remains long after the sweetness of low price is forgotten” (Benjamin Franklin, 1775). The sentence, even being quite old, is yet very up to date, as maintenance procedures and its deviations must follow strict rules and manuals to allow them to be successfully complete, giving to dispatchers and flight crews the capacity to make proper judgement whether it is safe or not to proceed with a take off.

Chapter III

Methodology

In this chapter, data sources and comparison methods will be presented. This study was designed to be completed in two major parts: a literature review of all documentation available in the Brazilian legislation repository regarding the application of CA-MEL and a compilation of the effects of non-scheduled maintenance in two major airlines in Brazil that currently operate a fleet of Airbus A32F.

In light of all current legislation in Brazil, the self dispatch of some malfunctions is something that could be done. This research also compiled all legislative records available in the USA and EU to compare the regulatory acts in the respective countries, allowing Brazilian regulators to create and approve supporting regulations to the dispatch made by crewmembers.

The Methodology section of this study is designed to present comparative data regarding the OTP of those airlines, and its possible mitigation if CA-MEL could be applied by that time.

Data Source(s), Collection, and Analysis

For the conduction of this research, three main data sources were taken into consideration. The first one is the compilation of all current legislation available in ANAC's repository. That legislation was benchmarked against FAA and EASA's to assess the differences against themselves. The second one is the delay records for two airlines that operate the Airbus A32F in Brazil. Those tables were prepared, the data was depured and analysed to ensure that only data related to Gate Returns and unscheduled maintenance were taken into consideration. The last data source took into account, for

reference purposes only, the MEL of the Embraer 190/195 aircraft, the only aircraft being operated in Brazil with a MEL structured and prepared for CA-MEL applications by the time this research has been conducted. This was used to compare the malfunctions and to prove that the execution of those procedures by flight crew, in coordination with maintenance personel, is safe and feasible.

Researchers are aware that manuals differ between different manufacturers, but we believe that those manuals could be used as a starting point for this research.

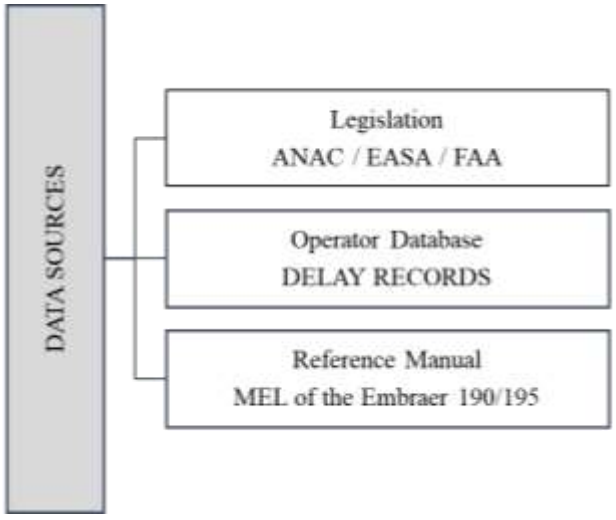


Figure 4: Main Data Source

All the data presented in this research were secondary, being collected from pre-existent databases, therefore not being collected by the research. The data collection process took into consideration several factors, like ethics, confidenciality and privacy, so those data would not be misused.

The spreadsheets used for the delay code registration were obtained from two major airlines. These data are registered following a two-letter delay code, that specifies the delay causing agent. This agent is required to present a form statint the causes of this delay and the actions taken to correct the malfunction and allow the airplane to depart.

For the purpose of this study, only delays recorded as “maintenance” were used, as the other ones are not within the scope of this research. Although the main focus on the work is based on the investigation of delays recorded as “Ground Turn Back”, where the aircraft has already left the departing gate towards the runway for takeoff, delays recorded in smaller bases were also taken into account.

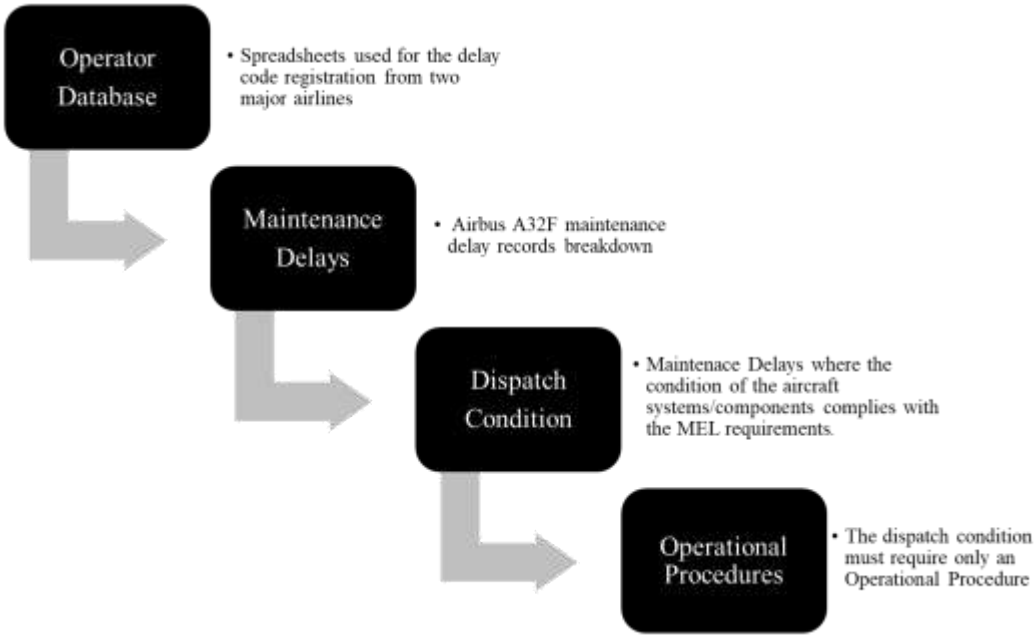


Figure 5: Data Analysis Process

The research was conducted based on the compillation of all delays recorded in the period of 2016 to 2020 and manually cleaned to obtain the mean, the average and the total delay time that could be avoided with the implementation of CA-MEL.

Delays recorded as “Ground Turn Back”, when the aircraft returned to the departing gate after taxiing out were taken into consideration, when attributed to the maintenance areas.

It is important to highlight that delays recorded with time of ”0” or “999” were not considered, as they intoxicate the obtained data, making it harder to classify. These events were considered as unaccurate and were cut of the research. Airbus’ Operational Interruption Cost Model for the A320 family was used to obtain the results found at the results part of this research.

The resulting costs vary with aircraft model (due to the different passenger capacity). To mitigate these errors, an average value has been calculated to allow calculations to be properly obtained.

Methodology Illustration

To illustrate the work methodology, below is a step-by-step analysis of some fictitious events:

- First Step – Operator Database

  At this stage, the objective is to obtain all the delay records of the two airlines under study to segregate only the technical events related to the Airbus A32F fleet.

DATE	FLEET	ACFT	DELAY TYPE	IATA DELAY CODE	DURATION (MIN)
05-24-2019	A320F	XX-XXX	TECHNICAL	43 – NON SCHEDULED MAINTENANCE	39
02-27-2020	B767	XX-XXX	DOCUMENTATION	27 – DOCUMENTATION PACKING	26
03-13-2020	B777	XX-XXX	PASSENGER AND BAGAGGE	13- CHECK-IN ERROR	56
04-28-2021	A320F	XX-XXX	TECHNICAL	43 – NON SCHEDULED MAINTENANCE	45
05-30-2021	EMB195	XX-XXX	AIRCRAFT AND RAMP HANDLING	37 – CATERING	38
08-07-2021	A320F	XX-XXX	TECHNICAL	46 – AIRCRAFT CHANGE	115
...	...	...	...		...

Figure 6 : Ficticious Operator Database

- Second Step – Maintenance Delays

With the A320F technical delays segregated, each event's technical reasons and the respective ATA Code will be obtained.

DATE	FLEET	ACFT	MECHANICAL INTERRUPTION	DURATION (MIN)	ATA	DESCRIPTION
05-24-2019	A320F	XX-XXX	DLY	39	30	WING ANTI ICE L VALVE OPEN
04-28-2021	A320F	XX-XXX	DLY	45	28	FUEL ENG 1 LP VALVE OPEN
08-07-2021	A320F	XX-XXX	GTB	115	74	ENG 2 IGN A FAULT
...	...	...	...	...	...	...

Figure 7 : Ficticious Maintenance Delays Database

- Third Step – Dispatch Conditions

  All messages will be analyzed and the release condition of each item will be verified. In other words, it will be confirmed if the fault message is possible to be released according to MEL or if the item is NO-GO. In addition to the dispatch condition, the type of procedure required will also be verified: Operational (o) and/or Maintenance (m). In the example, of the three events analyzed, only two of them meet the required dispatch condition, and of these two events, for the study in question, only one of them meets all the criteria: MEL Release with ONLY Operational Procedure.

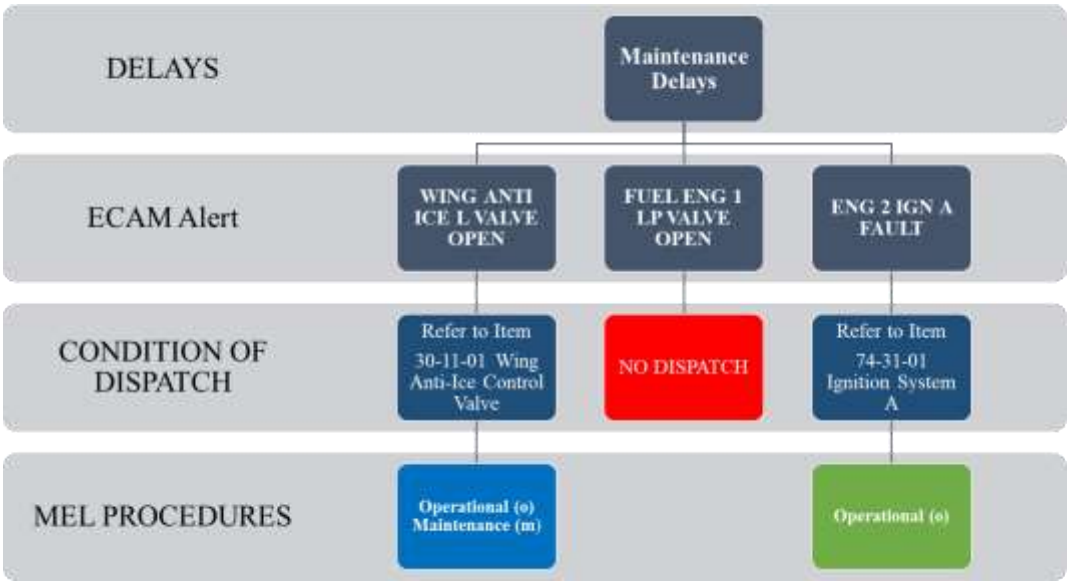
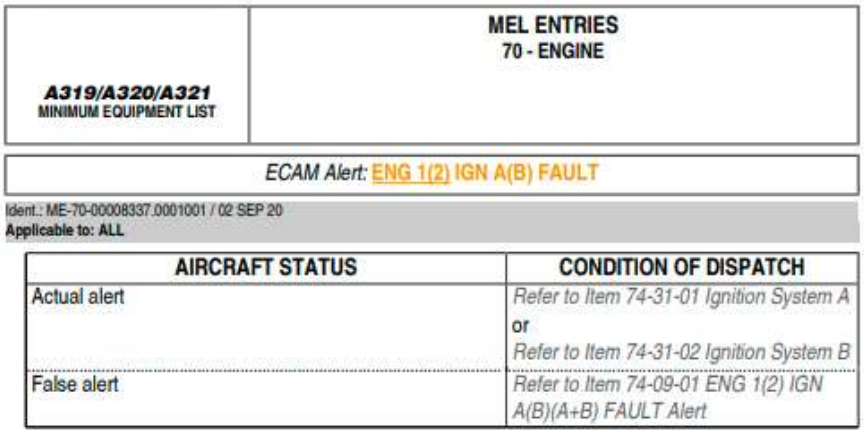


Figure 8 : Dispatch Condition Analysis

- Fourth – Operational Procedures

  The defined sample will contain only the events that generated impacts and that are subject to MEL release, considering that, during the analysis, the premise that the MEL release must mandatorily contain only Operational Procedure (o) was adopted.



A319/A320/A321
MINIMUM EQUIPMENT LIST

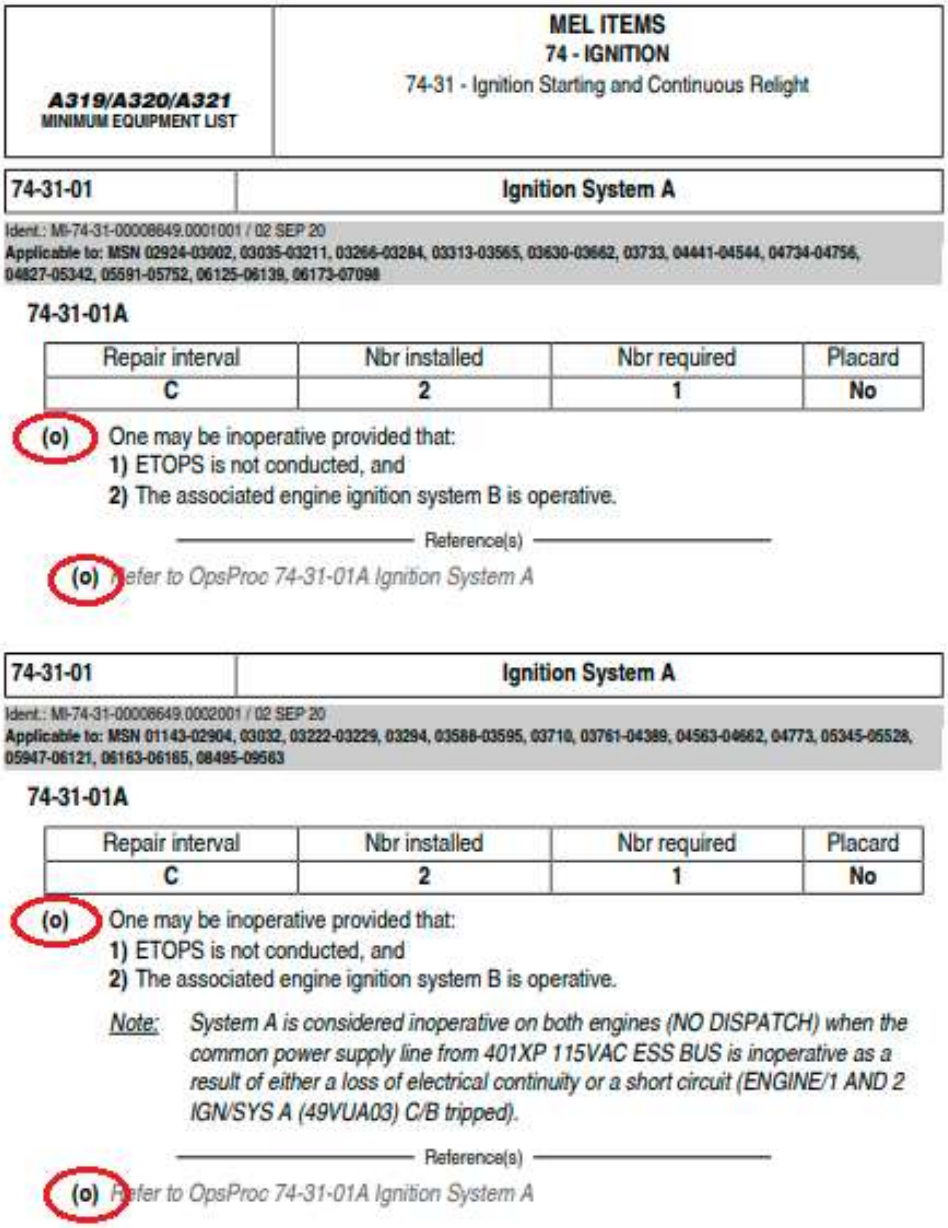
MEL ENTRIES
70 - ENGINE

ECAM Alert: ENG 1(2) IGN A(B) FAULT

Ident.: ME-70-00008337.0001001 / 02 SEP 20
Applicable to: ALL

AIRCRAFT STATUS	CONDITION OF DISPATCH
Actual alert	*Refer to Item 74-31-01 Ignition System A* or *Refer to Item 74-31-02 Ignition System B*
False alert	*Refer to Item 74-09-01 ENG 1(2) IGN A(B)(A+B) FAULT Alert*

Figure 9 : MEL Entries Illustration – ATA 70



A319/A320/A321
MINIMUM EQUIPMENT LIST

MEL ITEMS
74 - IGNITION
74-31 - Ignition Starting and Continuous Relight

74-31-01	Ignition System A

Ident.: MI-74-31-00008649.0001001 / 02 SEP 20
Applicable to: MSN 02924-03002, 03035-03211, 03266-03284, 03313-03565, 03630-03662, 03733, 04441-04544, 04734-04756, 04827-05342, 05591-05752, 06125-06139, 06173-07098

74-31-01A

Repair interval	Nbr installed	Nbr required	Placard
C	2	1	No

(o) One may be inoperative provided that:
1) ETOPS is not conducted, and
2) The associated engine ignition system B is operative.

Reference(s)

(o) Refer to OpsProc 74-31-01A Ignition System A

74-31-01	Ignition System A

Ident.: MI-74-31-00008649.0002001 / 02 SEP 20
Applicable to: MSN 01143-02904, 03032, 03222-03229, 03294, 03588-03595, 03710, 03761-04389, 04563-04662, 04773, 05345-05528, 05947-06121, 06163-06185, 08495-09583

74-31-01A

Repair interval	Nbr installed	Nbr required	Placard
C	2	1	No

(o) One may be inoperative provided that:
1) ETOPS is not conducted, and
2) The associated engine ignition system B is operative.

Note: *System A is considered inoperative on both engines (NO DISPATCH) when the common power supply line from 401XP 115VAC ESS BUS is inoperative as a result of either a loss of electrical continuity or a short circuit (ENGINE/1 AND 2 IGN/SYS A (49VUA03) C/B tripped).*

Reference(s)

(o) Refer to OpsProc 74-31-01A Ignition System A

Figure 10 : MEL Item Illustration – Ignition System A

Cost Analysis

To better obtain and analyze the results and predict the impact of delays caused by unscheduled maintenance, the researchers used Airbus' cost model for operational interruptions. All of these costs take into consideration the South American average labor cost for both maintenance personel and flight crews, an airline with medium cost profile,

in a moderate density cabin layout. All these costs are estimated, based in the manufacturer's previous experience. These values are used for aircraft selling purposes and for financial planning among airlines and business case studies.

The prices estimated do not include the cost for component repair, and include the following costs:

- Fuel consumption: Aircraft must remain with APU running in order to provide refrigerated air for the passengers, to keep the cabin within an acceptable temperature range;
- Airport and navigation: Some airports charge airlines by the hour to remain on a parking stand while maintenance services are being provided. Airports may also charge airlines twice for the gate return, as often aircraft may occupy a different gate than the original one.
- Crew costs: Airlines often pay crewmembers by the hour, so these costs increase as aircraft remain parked with passengers onboard, while maintenance procedures are being performed.
- Passenger services: these costs are related to meals and passenger services, like accommodation, phone calls, reaccomodation in another flight, missed connections and ground transportation.
- Passsenger remedies: these costs are related to passengers being endorsed to a different carrier, reacomodation, ticked refunds and financial compensations. These costs tend to be extremely high in Brazil as the justice system often understand those as "risks of business", even if proved that the delay was not on airline's account (weather, for example);

- Handling services: these costs reflect the need for luggage services, additional cabin cleaning and disinfection (sometimes required by local health authorities), stairs, pushback truck and ground personnel.
- Ownership: costs regarding the leasing rate of aircraft and its utilization.

When considering these costs, it is important to notice that some costs are empirical and, therefore, hard to predict. These costs are excluded from the manufacturer's estimative and were kept out of the scope of this research. These costs are related to the loss of revenue due to passengers loyalty and the knock-on effect that these delays may cause in the airline's network (effect on subsequent flights).

The costs, when considered for all airlines involved in this research were arithmetically averaged, as they almost don't differ from each other, due to the similarity in the airlines cost composition. They increase in a non-linear way by blocks of 15 minutes. The costs are presented in the table below:

Time (minutes)	15	30	45	60	75	90	120	180	240	300	360
Average cost (U$)	1967	3167	4567	6067	6300	8033	11400	17400	21700	24167	26133

Table 1: Time frame and cost estimative for delays

If placed in a graph, its possible to see that the interaction between time frame and costs grows in a near-linear way, allowing averages and arithmetical assumptions to be made.

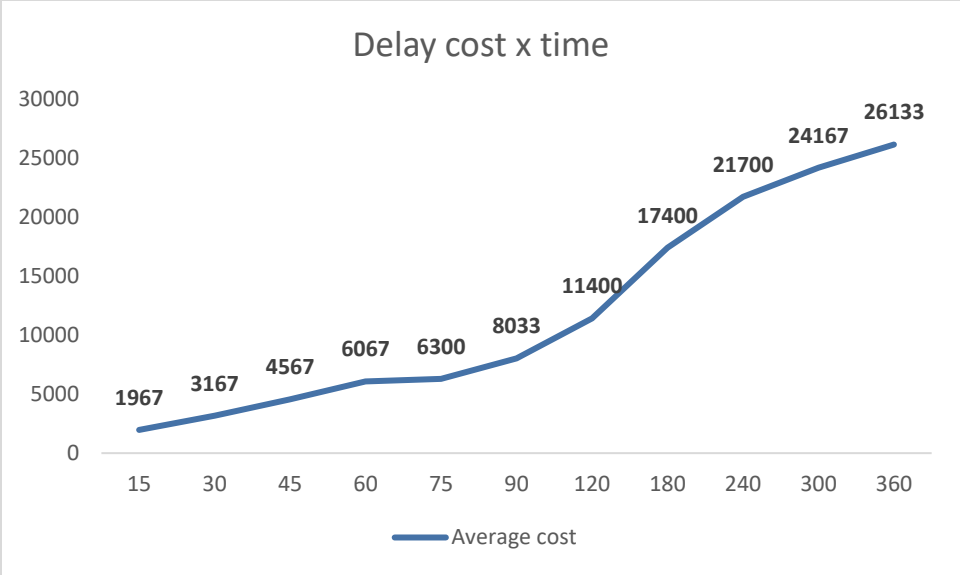


Figure 11: Delay cost and time interaction

Chapter IV

Conclusions

This research project aimed on finding possible cost reductions directly originated in unscheduled maintenance events, and to observe the overall impact of unscheduled maintenance interventions to an airline's OTP. This can be measured in gereral terms by analyzing the total technical delay hours observed in an airline's network and compare it to possible delays that could have been avoided due to its simplicity. Those delays generate costs, measured by airplane manufacturers, and available to customers.

The three main conclusions that became possible with the completion of this research were:

- **Conclusion One- GTB General Cost Reduction**
    - **Data Gathering** - General Cost Reduction is deemed as an opportunity to reduce the average cost directly caused to the airline following a GTB event, when the aircraft has already left the departing gate towards the runway for takeoff, and needs to return to gate due to maintenance reasons. The involved cost is about crew delays, fuel, engine cycle, and all direct costs related to those events. This cost can be considered as a hard cost, as they are tangible. These costs can have explicit figures attributed to it. They were measured by comparing all CA-MEL opportunities versus all delays followed by a GTB event registered in a five-year period (mid 2016-mid 2021), comparing the results, and multiplying by the estimated cost by the manufacturer. The research considered the databases of two major Brazilian airlines that

currently operate a fleet of Airbus A320 family (A319, A320 and A321).

- **Results-** The results observed for this first topic were a combined cost calculation, considering both airlines and all delays involved. The findings generated an estimated combined savings of U$1.239.833, coming from 14.769 minutes and 221 flights.
- **Conclusion-** The amount of money spent with GTB events could have been significantly reduced if CA-MEL was used. The result would save precious time and money to airlines, as well as increasing the operational efficiency. The implementation of these changes is a collective effort gathered between interested airlines and local regulatory agencies**.** (See Recommendation One).

- **Conclusion Two - Network Disruption Impact Reduction**
  - **Data Gathering**- The collected data regarding the impact on airline's network was obtained by classifying the delay reports according to the flight origin, to prove that hub-and-spoke networks are more exposed to delays and can generate a huge impact to the whole network, as most of the airline's flights arrive and depart from its main hubs.
  - **Results-** The consequences to the six busiest airports in Brazil add an amount of 139 flights delayed out of 221 total analyzed flights, representing 62.9% of all delays, generating an impact of 9.422 minutes of delay to the airline's networks.

- **Conclusion**- With the implementation of proper CA-MEL utilization by those two major airlines, these disruptions and its consequences could easily have been avoided.

- **Conclusion Three - CA-MEL Supporting Legislation Improvement Opportunity**
  - **Data Gathering** - Regarding the implementation of proper CA-MEL regulation, researchers found that there is enough space for proper regulation supporting CA-MEL and its applications in the daily routine of Brazilian commercial aviation. Our current legislation does not clearly state where and when is an aircraft to be considered as "dispatched" and where is the last point where a return must be performed for the aircraft to be legally dispatched. In Brazil, the only supporting legislation is RBAC part 121.628, but its text is rather nebulous and the directive has limited impact and its vague wording makes it difficult to enforce. This text puts on operators' shoulders all the responsibility of the procedure, not acting according the just and fair culture currently presented by airlines.
  - **Results –** Among all legislations currently supporting Brazilian civil aviation industry, we believe that RBAC 121.168 has paragraphs that need improvement, to clearly state rules and procedures to be followed to certificate a CA-MEL list to be used by pilots in case of malfunctions.

- **Conclusion –** RBAC 121 should include a paragraph that explicitly tells operators and crewmembers about the desired procedures to enable airlines to safely implement a CA-MEL routine in its operations. (See recommendation two).

Background

The approved MELs used by major airlines in Brazil compile a total amount of 463 possible malfunctions that can be presented during the aircraft's operation. Those malfunctions are detected automatically by onboard systems and self monitoring computers and built-in tests.

After analyzing all the lists and the provided information, researchers concluded that only messages without any kind of maintenance procedures and only with simple operational procedures (like turning off a switch or rotating a knob) may be subject to self-release. All messages and its consequences were analyzed and from this ammout, a total of 95 opportunities were found where self dispatch could be done by flight crew, minimizing future impacts.

The total of GTBs reported were distributed according to the departure airport, increasing the relevance of the operational efficiency increase in a hub-and-spoke airline network.

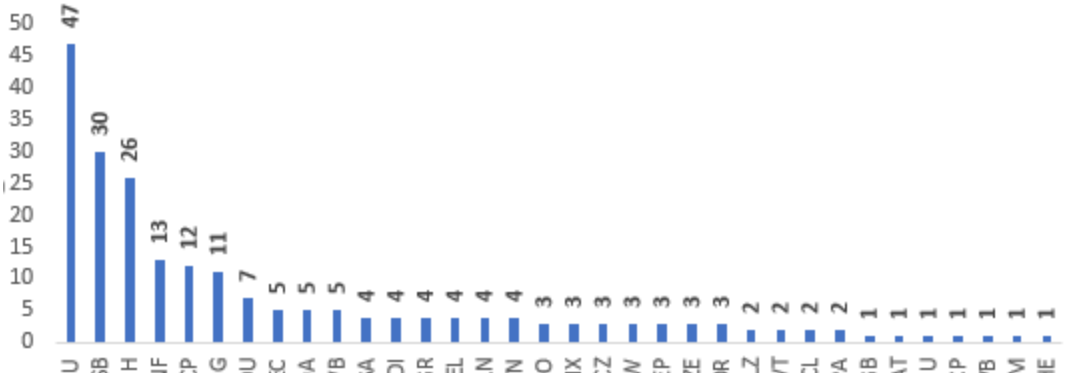


Figure 12: GTBs by departure base

These events generate severe consequences to an airline's network, as spare airplanes are rarely available and crew regulations sometimes imply in the change of crewmembers, as they cannot work beyond their legal barriers.

To avoid these delays, proper legislation supporting CA-MEL must be implemented in the Brazilian aviation context, as the way it is being currently presented, it does allow a gap that might cause airlines and pilots to both become accountable to all safety events related to those delays. This supporting legislation is extremely important in order to allow both operators and pilots to comfortably perform these dispatches, without becoming accountable to the future events.

As a mean of comparison, the following chart depicts all hard costs attributed to avoidable GTB events in the two major Brazilian airlines from mid 2016 to mid 2021. These costs grow linearly as the number of events increase. Researchers believe that

collective efforts should be implemented to reduce the amount of money spent with these events.

Note that only information from 2S2016 until 1S2021 were taken into

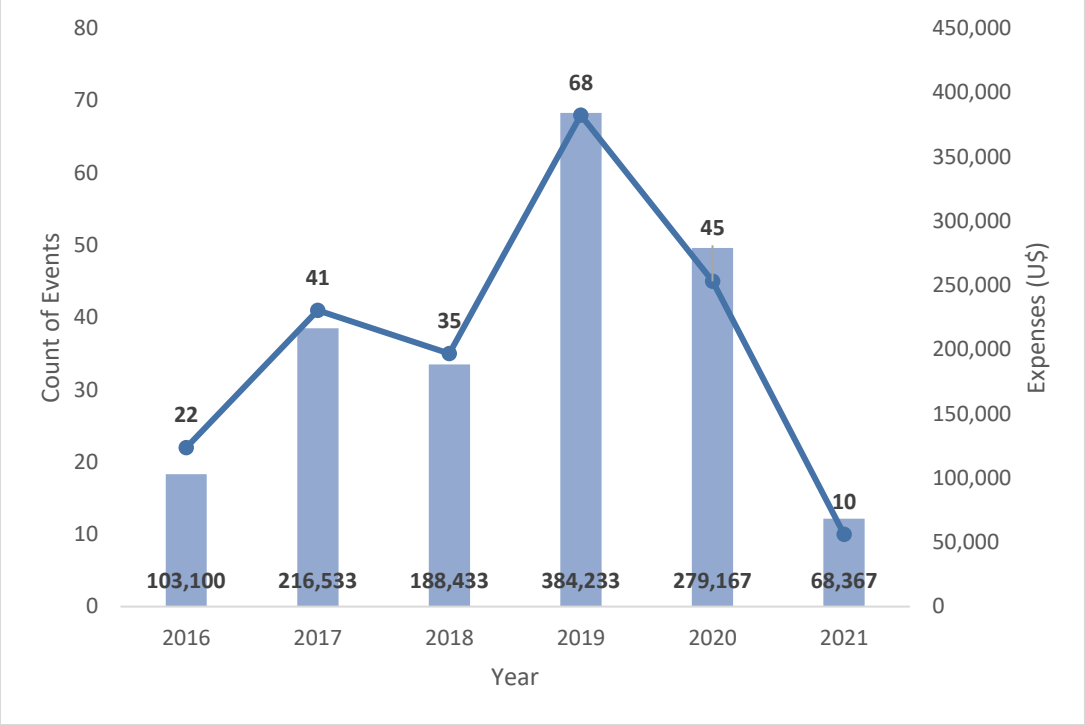


Figure 13: GTB events and costs by year

consideration, as these were the only database available at the time this research has been conducted. The calculation was made based on the Airbus Operational Interruption Cost Model for Airbus A32F. This cost takes into consideration all kinds of aircraft currently flyin on the A32F family. As the costs depend on the aircraft type (due to the different passenger capacity), an average value has been calculated to allow classification by event, according to the time of delay.

Adding up to these costs, there are several costs not directly related to the GTB events, that cannot be left out of the math. These costs are considered as soft costs. They are non-tangible, as they are related to flight cancelations, network disruptions, airline

image and reputation, customers loyalty and also future lawsuits that may be originated in those delays.

Chapter V

Recommendations, Future Research and Lessons Learned

Recommendations

This capstone project has been able to found cost reduction focus by allowing or recommending the airlines to follow new regulations and new operational procedures. Brazilian commercial airlines could improve their operations, save costs and avoid possible delays by considering it.

Following, are listed the three main recommendations:

- **Recommendtion One-CA-MEL proper implementation in the operators MEL.**
- **Recommendation Two- RBAC 121 improvements regarding CA-MEL dispatch.**
- **Recommendations Three- Improvements on data registrations on the maintenance database**

Background

Recommendations One and Two

For the first and second recommendation, by increasing the CA-MEL implementation and proper dispatch, the airlines could save costs as well as keep their on time performance keeping the operational safety.

Recommendation Three

For the third recommendation, we've found an opportunity to make more organized and securely recorded maintenance events, including MEL and CA-MEL events were identified. All registrations made by airlines are carried out according to the

point of view and words of the mechanic involved in the event. The information normally stays out of standard and the data record is not always reliable in terms of correct classification.

The conclusion is a recommendation to insert a new data logging procedure and to standardize the logging of MEL and CA-MEL events.

Future Research

- Possible cost reduction on maintenance department (headcount) where the proper use of the CA-MEL dispatch could avoid the presence of the mechanic.
- Possibility of a standard maintenance logbook writeup training to be delivered to mechanics and crewmembers.

Lessons Learned

- During the research, we found a large availability of literature available on the subject, which contributed to the understanding and development of the project. However, as we work with data from two different airlines, there was a challenge to standardizing the data to build a uniform and reliable database.
- The objective of the research was to evaluate the benefits of implementing the CA-MEL release and the results were satisfactory and are in line with our initial expectations, a fact that may contribute to the revision of RBAC 121, in addition to minimizing collateral damage to the airlines' image before the customers due to improved punctuality of operations.

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