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Engine Light Repair Shop Evaluation for a Brazilian Airline

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Embry-Riddle Aeronautical University

Aviation Management Program – Class of 2019

EMBRY-RIDDLE
Aeronautical University
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ENGINE LIGHT REPAIR SHOP EVALUATION FOR A BRAZILIAN AIRLINE

by

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Embry-Riddle Aeronautical University

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This Capstone Project was prepared and approved under the direction of the
Group's Capstone Project Chair, Dr. Leila Halawi
It was submitted to Embry-Riddle Aeronautical
University in partial fulfillment of the requirements
for the Aviation Management
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Xxxxx X. Xxxxxx, XX

Subject-Matter Expert

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Date

Acknowledgements

Whatever you do, work at it with all your heart, as working for the Lord, not for human masters,

Colossians 3:23

We would like to thank those who truly work for an honest, ethic, peaceful, and better world.

Abstract

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Title: Engine Light Repair Shop Evaluation for a Brazilian Airline

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The maintenance cost of a commercial aircraft comprises airframe, components, and engines. The most expensive of them are engines, which may represent up to 60% of an aircraft cost, and therefore will have a significant impact on any airline finance. As a result, engine fleet maintenance management is crucial for any airline sustainability. Apart from heavy maintenance where life limited parts are replaced and its performance restored, aircraft engines are often required to come off wing for light repair due to operational issues like foreign object damage, high oil consumption, and vibration issues. In other cases, even though being operational, engines are required to come off the wing and undertake repair processes to comply with lease return conditions. Although these light repairs may be simple and relatively short in time, they require the engines to be transported to dedicated repair shops impacting engine availability due to shop slots unavailability and the logistics. This drives airlines to have additional spare engines on its fleet increasing its operating costs. This project is aimed at evaluating the pros and cons any Brazilian airline may have if it decides to have its engine shop for light repairs. Due to the complexity of the engine repair process, this project will be focused on a specific repair for a specific engine, which, if developed internally, may allow airlines to expand their light repair capability and, in the long term, improve engine availability.

Table of Contents

Page

Capstone Project Committee ii

Acknowledgements ii

Abstract............ iii

List of Tables............ i

List of Figures............ ii

Chapter

I Introduction 1

Project Definition............ 2

Project Goals and Scope 3

Definitions of Terms............ 4

List of Acronyms [in alphabetical order]............ 6

II Review of the Relevant Literature............ 7

Maintenance 7

Regulation for Repair Stations 17

Engine Repair Landscape 20

Brazilian Current Exchange............ 22

Engine Maintenance Cost 23

Custom Clearance, Import, Export 24

Homologation............ 28

Summary............ 3030

III Methodology............ 311

Turnaround Time and Costs Internal Repair 342

IV Outcomes 377

V Conclusions and Recommendations 411

References 42

List of Tables

Page

Table

1 Process Steps in Unscheduled Maintenance Adapted from “Industrial aviation management: A primer in European design, production, and maintenance organizations (American English, organiSation = British English).” by Hinsch, M. 2018, p *196*...10

2 Fundamental Engine Maintenance Procedure. Adapted from Hinsch, M. (2018).

Industrial aviation management: A primer in European design, production and

maintenance organizations. 15

3 Comparison of different line and base maintenance checks for widebodies Adapted from “Industrial aviation management: A primer in European design, production and maintenance organizations.” by Hinsch, M. 2018, p 194.......................16

4 Content addressed by RBAC 145, retrieved from https://www.anac.gov.br/assuntos/legislacao/legislacao-1/boletim-de-pessoal/2018/6s1/anexo-ii-rbac-no-145-emenda-no 02 18

5 Estimated turnaround time for repairs. 27

6 Repair costs 28

7 Comparison between TAT for outside and inside repair 29

8 Cost (BRL) for internal repair...31

9 Cash flow (BRL) for external repair next five

years……………………………………32

10 Net present value (BRL) for accumulated saving next five years if the repair is internalized…………………………………………………………………......35

List of Figures

Figure Page

Figure 1. Difference between Theory and Practice. Adapted from “Aviation maintenance management”, by Kinnison, H. (2004), p 6. 8

Figure 2 Restoration of a System. Adapted from “Aviation maintenance management”, by Kinnison, H. (2004), p 7. 11

Figure 3. EGT along engine life. 13

Figure 4. Extract from RBAC 145 Maintenance Organization for Aeronautical Product Amendment 2, retrieved from https://www.anac.gov.br/assuntos/legislacao/legislacao-1/boletim-de-pessoal/2018/6s1/anexo-ii-rbac-no-145-emenda-no-02 18

Figure 5. CFM56-7 main MROs, retrieved from MROs website. 22

Figure 6. BRL / USD exchange rate, ANAC (2019) and Brazil Central Bank. 23

Figure 7. 2017 World MRO Spend by Segment. Adapted from IATA 2017 Maintenance Cost Task Force 24

Figure 8. 2027 Projected World MRO Spend by Segment. Adapted from IATA 2017 Maintenance Cost Task Force 24

Figure 9 Import Dispatch. Adapted from RFB. 27

Figure 10 Repair Cycle Turnaround Time 33

Figure 11Cost comparison between External and Internal Repair 37

Figure 12 Cash flow for External and Internal Repair. 39

Figure 13 Net Present Value for Accumulated Savings. 39

Figure 14 Turnaround time saving due to internal repair. 40

Chapter I
Introduction

The manufacturing performance of aircraft components is relatively more important than the final sales price factor, the investment is high, and the control is thorough. (Mergent, 2019). MRO, Maintenance, Repair, and Overhaul is a service provider (which may include an OEM) that can perform maintenance, repair and overhaul functions on an Aircraft or Engine (Scheinberg, 2017). Prices are very high compared to production, this is overwhelmingly reflected in costs at MROs, and airlines are paying this for replacement. (Vieira, 2016). An MRO must be certified by an applicable Aviation Authority (Scheinberg, 2017). All these requirements, in conjunction, contribute to a limited number of engine MROs in the world and especially in Brazil. As a result, engine repair cycles may not be as short as desired by Brazilian airlines due to limited repair stations available in the market or long transportation time to import-export engines.

IATA´s Maintenance Cost Task Force, estimated the global MRO in 2017 at USD 76 Billion, excluding overhead (IATA, 2018). This value comprises 42% spending on engines, 21% spending on components, 20% spending on base maintenance, and 17% spending online maintenance and represents around 11% of airlines operational cost (IATA, 2018).

Therefore, it is clear that engine fleet optimization is of paramount importance for any airline finance. This work intends to provide insight on how Brazilian airlines could improve its repair cycle through internalizing a specific repair for a specific engine.

Project Definition

Due to the high technology, high costs, expertise, and complexity involved in the design and certification of an aircraft, there are only a few manufacturers in the world. According to IATA´s MCTF, in FY2017, the world fleet count for all active aircrafts in commercial operations was 25,870, being 80%, which are manufactured by Airbus and Boeing. The other 20% is represented by Bombardier, Embraer, Fokker, ATR, and others. (IATA 2018). In the construction of large aircraft production, the negotiations to build large Turbofans engines are from large companies such as GE - General Electric, United Technologies, PW with the Pratt & Whitney brand, and Rolls Royce that together surpass 93 % from the market. (The Economist June 1st, 2019). There is no doubt that 93% is a very high percentage. The result is that it severely contributes to a reduction in the available choices for any airline when considering engine fleet selection. The lack of multiple engine manufacturers in the market creates a condition close to a monopoly where any engine related cost is imposed by a few manufacturers, leaving for airlines limited or no options for bargaining.

It was not by chance that, in 2016, IATA filed complaints against CFM with the European Commission's competition office alleging abuses of dominant positions by manufacturers of aviation equipment. The allegation resulted in a conduct policy aimed at restoring fair commercial practices in the aviation engine market. The conduct policy was released by CFM in July 2018 with 41 pages. CFM broadly said that its service licenses and warranties do not discriminate against the use of non-OEM material (Gubisch, M., & Hemmerdinger, J. (2018). Non-OEM material refers to spares developed under a parts manufacturer approval (PMA) and repairs devised under a designated engineering representative (DER) certificate (Gubisch, M., &

Hemmerdinger, J. (2018). The historic deal has implications beyond CFM and is intended to be a prime example for the other engine, as we will see below.

Beneficiaries include airlines, aircraft outsourcers, parts manufacturers, and MRO maintenance companies and third parties. (Aircraft Commerce, 2019).

Engines are very complex and precise machines that demand large investments in infrastructure such as bench tests, machines, tooling, and also know-how to be properly repaired. Also, the lack of dedicated training aligned with the level of specialization and expertise required for performing an engine repair makes it challenging to create a capable workforce. All these requirements, summed up, do not contribute to the development of engine repair shops in many places in the world and especially in Brazil.

When the repair is done locally in Brazil, airlines count only with one repair shop, which tends to offer little to no margin for slot allocation or pricing negotiation. As a result, engines may become unavailable for longer periods than desired what increases operational costs due to engine substitution for a spare engine. When the engines are sent to be repaired abroad, turnaround times tend to be high and also contribute to engine unavailability for longer periods. This project aims to identify insights for alternatives to reduce airline costs by improving engine fleet availability by developing the airline´s internal light repair capability.

Project Goals and Scope

This report has the objective of evaluating an alternative for a Brazilian airline to have an engine fleet optimized by developing internal capabilities to submit its engines to light repairs. It is assumed that the airline already has some MRO capability, but for airframe only and not dedicated to engine repair.

The study will focus on a specific repair procedure on a specific engine type. We will investigate if this is technically and economically feasible. It is projected that this scenario may contribute to a further and broader development of the airline repair capability in house. The ultimate aim of the study is to reduce the airline operational costs either by using its internal manpower or by improving its engine availability in a way that allows its spare engine fleet to be reduced.

The analysis of manpower consists of evaluating the training required to elevate the current know-how of the airlines' employees to the requirements needed to successfully perform the job as well as the gains it may offer for cost reduction. It is important to remember that the cost to repair an engine is comprised of material (new, used or repaired parts) and labor. The costs of material are typically controlled by the OEMs and offer little to no opportunity for cost reduction. The costs of labor may offer opportunities for cost reduction for two reasons: 1 - local manpower costs do not fluctuate with exchange rates; 2 – local manpower costs consist of pure cost and do not bring any profit margin within its value (whereas outside MRO values for labor bring the MRO´s profit margin). Considerations about repair costs taxation will also be taken into account for labor as well as material.

The analysis of improvement of engine availability takes into account the slot availability and repair TAT that may be obtained if the repair is conducted within the airline borders.

Definitions of Terms

ANAC ¨The National Civil Aviation Agency (ANAC) is responsible for civil aviation regulation and safety oversight in Brazil. ¨It was established in March 2006 (anac.gov.br, 2017).

EGT "The EGT, Exhaust Gas Temperature, expressed in degrees Celsius, is the temperature at the engine exhaust and a measure of an engine's efficiency in producing its design level thrust; the higher the EGT, the more wear, and deterioration affect an engine (Ackert, 2011). High EGT can be an indication of degraded engine performance, an exceedance in EGT limits can lead to immediate damages of engine parts and/or a life reduction of engine parts (Ackert, 2017).

IATA ¨The International Air Transportation Association (IATA) is the trade association for the world´s airlines, representing some 275 airlines or 83% of total air traffic¨. IATA ¨supports many areas of aviation activity and help formulate industry policy on critical aviation issues (iata.org, 2017).

LLP "Life Limited Parts (LLPs) are Parts which, when listed on the Aircraft or Engine Type Certificate datasheet or the OEM's instructions for continued airworthiness, must be permanently removed from service and discarded before a specified time (for example, Hours, Cycles or calendar limits) is achieved. Among the most significant life-limited items are engine disks and shafts (Scheinberg, 2017).

TAT "Turnaround Time is the time it takes for an engine to undertake an entire repair process. The TAT is counted in days, and it starts on the day the engine is removed from the wing and finishes on the day that the engine is returned to the company stock in a serviceable condition and ready for use.

List of Acronyms [alphabetical order]

ANAC National Civil Aviation Agency

DER Designated Engineering Representative

EASA European Aviation Safety Agency

EGT Exhaust Gas Temperature

FAA Federal Aviation Administration

FAR Federal Aviation Regulation

IATA International Air Transportation Association

LLP Life Limited Part

MCTF Maintenance Cost Task Force

MPD Maintenance Planning Document

MRO Maintenance, Repair and Overhaul

NDT Non-Destructive Testing

OEM Original Equipment Manufacturer

PMA Parts Manufacturer Approval

RBAC Regulamento Brasileiro de Aviação Civil

TAT Turnaround Time

In the next chapter, we will have a deeper review of the content related to this project, which is available in the literature.

Chapter II
Review of the Relevant Literature

This chapter has the purpose of informing the reader of a deeper familiarization with the concepts used in this project. To be more didactic and to facilitate learning, the literature review will be divided into subchapters.

Maintenance

Maintenance is summarized in an ongoing systematic process to ensure continuity of original operation with the same level of safety and reliability as the model. (Kinnisson, 2012).

In the real-world due to several constraints such as manufacturing, material, time, costs, etc. systems cannot be designed to 100% of perfection. However, every system is designed to a certain level of perfection that fits its intent. As time passes, due to wear and tear, there is a natural increase in the entropy of any system which characterizes its deterioration. This deterioration distances the current system condition from its original design intent and can be seen in Figure 1.

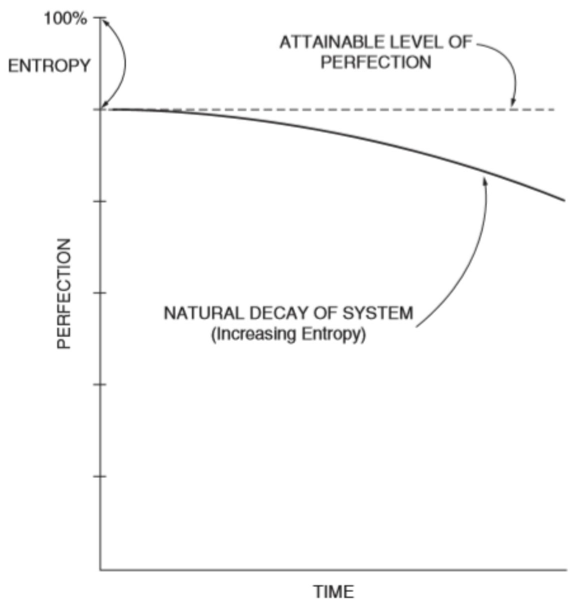

Figure 1. Difference between Theory and Practice. Adapted from "Aviation maintenance management," by Kinnison, H. (2004), p 6.

When the system deteriorates to certain levels still accepted by the operator, manufacturer, or regulator, it may continue to operate. However, an intervention is needed to prevent it from falling outside the limits of its design intents. This process is known as predictable, scheduled, or preventive maintenance and can be seen in Figure 2, curves a and b. Preventive or scheduled maintenance is usually done by means of scheduled inspections or condition monitoring. This usually happens because the aircraft has parts that must be periodically inspected at a certain time, which ensures the operability of the designed components. This inspection time is usually requested by the manufacturers in the MPDs. For example, on engines, LLPs replacement or EGT restoration are typically classified as scheduled maintenance because they can be predictable based on operation.

There are also times when the system deteriorates to unacceptable levels by the operator, manufacturer, or regulator at non-predictable pattern, usually sooner than expected. When this happens, an intervention is necessary to restore it to its original design intent. This process is known as unpredictable or unscheduled maintenance. The guideline is that problems should be observed in two parts, such as primary and secondary damage, to increase the availability of equipment and its systems as a whole, to reduce repair time and increase productivity. (Viles, 2007), it is also aimed at capturing relevant information for analysis.

Table 1

Process Steps in Unscheduled Maintenance Adapted from "Industrial aviation management: A primer in European design, production and maintenance organizations." by Hinsch, M. 2018, p 196.

1	Determination of the finding e.g., via inspection, exposure or record in the technical logbook
2	Documentation of the finding
3	Troubleshooting/root cause analysis considering possible secondary errors and risks
4	Assessment and classification of finding including identification of applicable maintenance instructions / approved maintenance data
4a	If standard maintenance data are insufficient: Obtain individual maintenance instruction from the responsible design organization
5	Determination of personnel qualification, material requirements, time and financial effort
6	Rectification and documentation of the processing

The unpredictable or unscheduled maintenance can be seen in Figure 2, curve c and d. Technical wear processes are not always predictable; this is a consequence of the fact that unpredictable processes (Hinsch, 2018). On engines, oil leakage, high oil consumption, abnormal vibration, foreign object damage are general types of unscheduled maintenance because they cannot always be predictable.

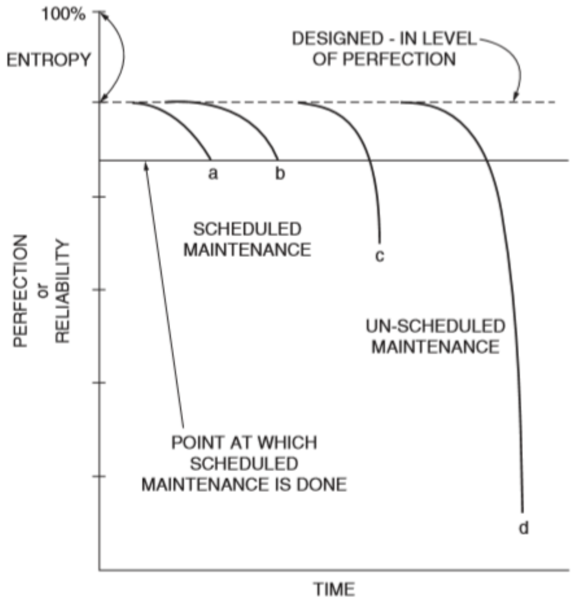

Figure 2 Restoration of a System. Adapted from "Aviation maintenance management," by Kinnison, H. (2004), p 7.

The term maintenance is also referred to as all actions which delay wear and maintain planned conditions. Just as they delay wear and maintain planned conditions he term overhaul is usually used to describe all actions taken to re-establish the intended condition of a system or component.

Increasing and improving equipment availability is a focus of maintenance service, which means improving reliability and reducing repairs. (Viles, 2007). As a result, it requires high organizational flexibility in terms of factual conditions, space, as well as scheduling and capacities (Hinsch, 2018):

Factual flexibility needs because it is understood that it is a maintenance activity, often complex work with few interventions. As a result, maintenance personnel shall be having a lot of knowledge and be very well educated. This causes workers to be gradually replaced by machines in maintenance activities that would be unlikely. (Hinsch, 2018).

Temporal and Capacitive flexibility It is fundamental for purposes of component; failures in equipment and assemblies are unstable; as a result, necessary resources can be planned to a limited extent. Maintenance activities, also, production downtimes, are very expensive and should be taken seriously considering periods, and this can often happen (Hinsch, 2018).

Spatial flexibility It is important, as far as possible that the maintenance is performed within its environment, due to the possibility of moving the equipment, this happens due to several factors, such as distance, weight, and others. (Hinsch, 2018).

The three main areas of concern on a commercial aircraft are components, engines, and airframe. They are thus subdivided to demonstrate the importance of their main areas and the cost difference between them over their lifetime, which in short has in common the impact on market value. (Ackert, 2010).

Engines are designed to operate several cycles (which are driven by their life-limited parts - lifetime of LLPs, in most cases, are between 15,000 and 30,000 cycles (Ackert, 2010)) under certain operational limits. One of the main operational limit is the exhaust gas temperature (EGT). The EGT is reported in the unit of measurement in degrees Celsius, and its purpose is to inform the engine gas temperature, which relatively speaking, engine deterioration can occur with the high value or degree of EGT. (Ackert, 2010). High EGT can cause damage to parts and shorten component life, so EGT indication and performance must be monitored not to exceed limits. (Ackert, 2010).

When an engine approaches its EGT limit, it is time for it to be repaired. Figure 9 illustrates the EGT increase along the engine life.

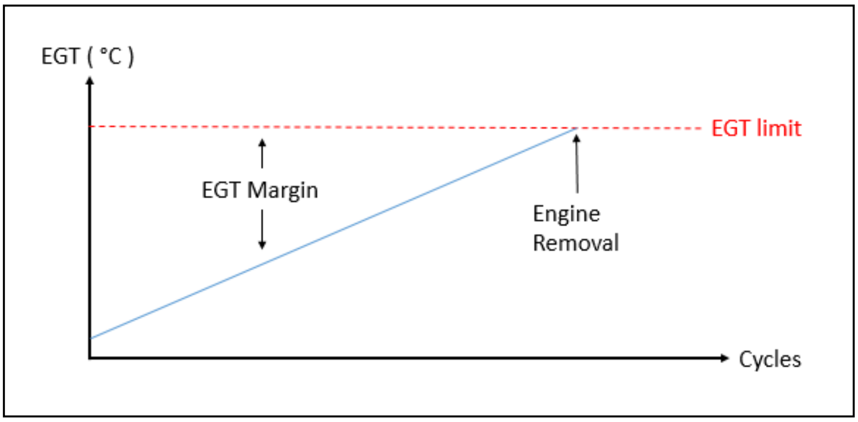

Figure 3. EGT along engine life.

Engines may come off the wing on a scheduled or unscheduled basis. Engines are typically removed from the wing on a scheduled fashion to be submitted to shop visits and have their LLP replaced or their EGT restored. Other times they can be removed from the wing to be sent to 'hospital' shops, which carry out minor repairs and fan blade changes, but cannot perform module disassemblies and shop visits (Aircraft Commerce, 2001).

Airlines routinely monitor engine utilization by counting its cycles and measuring its exhaust gas temperature through an aircraft health monitoring system. With the collected values plus considering the current condition of an engine and its projected utilization, its maintenance may be scheduled. Scheduled removals are engine maintenance events typically driven by: 1 - engine life-limited parts (LLP) expiration, 2 - poor performance (EGT loss), 3 - compliance with the engine return conditions to its lessor (either by being kept on the shelf to save its cycles or by being submitted to a repair to comply with its redelivery condition to its lessor) or 4 - even staggering purposes. Staggering is the process of removing an engine from the wing for a later use.

There may be operational issues, however, which demand the engines to come off the wing on an unscheduled basis. Unscheduled removals are typically driven by operational issues such as foreign object damage, abnormal fuel or oil consumption, vibration out of limits, among other factors. In all cases, a minor intervention or a minor repair turns out to be necessary to return the engine under the same conditions as normal to operate so that it can be back to the wing.

The lifetime of an engine is fully persuaded by its thrust rating, either by the number of cycles or hours of operation. (Ackert, 2011).

After being removed, engines may be kept on stock, redelivered to its lessor, or submitted to repair process. Either scheduled or unscheduled removals have an impact on airline finance and require a spare engine to sustain the aircraft in operation while the removed engine is under the repair cycle.

Everything must be taken into account in costs, such as fleet model, work methodology, maintenance scheduling, task planning, engine types and accessories, and so on. (Aircraft Commerce, 2018).

The maintenance process to avoid workshop engine costs can be broken as follows:

1 - Material Cost: primary cost driver, material replacements are around 60% to 70% of the cost of a machine shop visit; this can still increase costs if LLP parts require replacement.

2 - Direct labor: accounts for approximately 20% to 30% of the total cost;

3 - Repairs: accounts for 10% to 20%. (Ackert, 2011).

The type of aircraft and its engines vary greatly, so removal, repair, and installation procedures are complex.

Most of the time, however, it is easy to manipulate the way to connect and disconnect the hydraulic, electric, and pneumatic components, as well as the fuel lines, air intake and exhaust. (United States Flight Standards Service, 2018).

The typical repair or overhaul cycle for an engine can be observed in table 2. A reduction in the length of the repair cycle illustrated in figure 3 improves the engine availability, therefore, requiring fewer spare engine for the same airline.

Table 2.
Fundamental Engine Maintenance Procedure. Adapted from Hinsch, M. (2018). Industrial aviation management : A primer in European design, production and maintenance organizations.

Removal Transportation	Incoming Inspection Incoming Test Run	Disassembly	Cleaning Inspection NDT Repair Maintenance	Assembly	Test run QEC Buildup Completion	Transportation Installation Run up Test flight

Competitiveness among airlines only tends to increase, and any reduction in costs and is significant. (Fritzsche, 2014). Research and maintenance procedures have always been significant in research to ensure the shortest possible ground time or unavailable aircraft. (Fritzsche, 2014).

Apart from scheduled (preventive) maintenance and unscheduled (unpredictable) maintenance, maintenance can also be classified as Line Maintenance and Base Maintenance. Line maintenance is typically described as activities that are aimed at preserving the intended conditions of a component or system. Whereas base maintenance, under normal circumstances, refers to measures of overhaul. Base maintenance typically refers to activities that are aimed at restoring the intended conditions of a component or system. The technical depth to which the tasks or activities demands is the main driver for classifying maintenance as base or line. In general, the eligibility conditions for basic maintenance are stricter and more demanding than the line maintenance. As a rule of thumb, for aircraft, events below the Check "C" are usually considered to be line maintenance, and for engine events such as lube blade, oil filter replacement, boroscope inspection, chip detector inspection, trim balance are usually considered as line maintenance. C-checks, D-checks are typical aircraft base maintenance activities and engines LLPs replacement or EGT restoration are typically classified as engine overhaul.

Table 3

Comparison of different line and base maintenance checks for widebodies Adapted from "Industrial aviation management: A primer in European design, production and maintenance organizations." by Hinsch, M. 2018, p 194.

Check	Frequency	Manhours	Duration
Line Maintenance			
S-Check	weekly	10 - 50	3 - 5 hours
A-Check	every 4 - 8 weeks	50 - 250	Approx. 12 hours
Base Maintenance			
C-Check	ca. every 18 month	200 - 500	1 - 2 weeks
D-Check	every 6 - 10 years	30.000 - 50.000	4 - 8 weeks

It is important to highlight that due to the complexity of the aviation industry both, line and base maintenance, require a complete and dedicated organization to assure the performed services complies with all the quality and safety requirements. Lots of effort are required to plan the maintenance activities properly, allocate the dedicated resources, monitor the progress of the planned activities, control costs and document everything. Another fundamental aspect of maintenance is that the maintenance organization, before performing its designated job, needs to be certified by local or international authorities. A brief overview of regulations for repair stations will be covered in the next section.

Regulation for Repair Stations

As soon as an aircraft enters operation after being released from its manufacturer, its maintenance is ruled by local authorities to always remain airworthy throughout the operation. In general, every country or group of countries have their regulator for addressing aircraft maintenance and repair stations. Below we can find a specific country or group of countries, its regulator, and the regulation which governs the repair stations.

Table 4

Location, regulator, and regulation for repair stations.

Location	Regulator	Regulation
Brazil	ANAC	RBAC part 145
USA	FAA	FAR part 145
Europe	EASA	EASA part 145

Although each country or group of countries have their regulators, in practical terms, due to the intrinsic global characteristic of aviation, Brazilian Repair Stations Quality Departments often need to deal with international regulators such as FAA and EASA. The rules which govern aviation in each country can be found in each of the respective regulators for that country website. For illustration purposes, an extract from RBAC 145 can be seen in Figures 4.

Data da emissão: 14 de fevereiro de 2017 RBAC nº 145
Emenda nº 02

SUBPARTE A
GERAL

145.1 Aplicabilidade

(a) Este regulamento descreve como obter um certificado de organização de manutenção de produto aeronáutico e contém as regras relacionadas ao seu desempenho na manutenção, manutenção preventiva ou alteração de artigos aos quais se aplica o RBAC 43. Este regulamento se aplica a qualquer requerente ou detentor de um certificado de organização de manutenção emitido sob este regulamento.

(b)-I Cada organização de manutenção que esteja certificada segundo o RBHA 145 ou que tenha requerido um certificado conforme esse RBHA até 8 de abril de 2013 poderá ser classificada de acordo com a seção 145.59 deste RBAC quando necessário, quando solicitar ou na primeira inspeção da ANAC, e deve se adequar às seguintes disposições deste regulamento, nos prazos especificados:

(1) até 8 de setembro de 2013: o parágrafo 145.151(a) deste RBAC;
(2) até 8 de março de 2014: os parágrafos 145.207(d) e 145.211(c) deste RBAC;
(3) até 8 de setembro de 2014: o parágrafo 145.163(a) e 145.209(e) deste RBAC;
(4) até 8 de março de 2015: os parágrafos 145.51(a)(1)-I, 145.53(d), 145.153 (b)(2)-I(i), 145.161(a)(2), 145.165(b), 145.209 (d)(2) e 145.209 (h) deste RBAC; e
(5) até 8 de março de 2016: o parágrafo A145.1(g)(ii) do Apêndice A-I deste RBAC.

Figure 4. Extract from RBAC 145 Maintenance Organization for Aeronautical Product Amendment 2, retrieved from https://www.anac.gov.br/assuntos/legislacao/legislacao-1/boletim-de-pessoal/2018/6s1/anexo-ii-rbac-no-145-emenda-no-02

The content addressed by RBAC 145 is vast, and any MRO which aims to service any Brazilian airline shall comply with it. Table 3 illustrates some of the aspects covered under RBAC 145.

Table 5

Content addressed by RBAC 145, retrieved from https://www.anac.gov.br/assuntos/legislacao/legislacao-1/boletim-de-pessoal/2018/6s1/anexo-ii-rbac-no-145-emenda-no-02.

GENERAL
Applicability
Definitions
Requirement for certificate and operational specifications
CERTIFICATION
Requirements for certification
Issuance of certificate
Validity and certification renewal
Amendment or certificate transference

Categories and Classes
Limitations of certificate
INSTALLATION, RESOURCES, EQUIPMENT, TOOLING, MATERIALS, TECHNICAL DATA
General
Requirements for installations and resources
Changes of location (address), installation or resources
[Reserved]
Requirements for equipment, tooling, materials and technical data
PERSONNEL
Requirements for personnel
Requirements for supervision personnel
Requirements for inspection personnel
Requirements for personnel authorized to approve an item to return to service
[Reserved]
Administration, supervision and inspection personnel records
Training requirements
Danger of goods training
OPERATIONAL RULES
Certification prerogatives and limitations
Activities performed at other locations
Maintenance execution, prev. Maintenance, alteration for cert. owner based on RBAC 121 / 135
[Reserved]
Maintenance organization manual
Content of maintenance organization manual
Quality control system

As we can see, the content covered by regulators is vast. This vast content covered by regulators is important to assure that only qualified shops can be able to work on aircraft and engine maintenance. As a result, only a few organizations in the world are capable of servicing engines due to the stringent requirements to do the job and, therefore, large financial investments needed. The subchapter below shows an overview of the engine MRO landscape.

Engine Repair Landscape

According to Market Research Future, the construction of large-level aircraft in the construction of turbofan jets is limited to 4 large companies, thus sharing 93% of the manufacturing. (The Economist June 1st, 2019). Similar situations, to a lesser extent due to the development of independent airline shops or independent repair stations, happens with engine MROs.

At this time, the older engine fleets are steadily declining due to the natural evolution of new-generation aircraft and engines introduced to the market. As a result, the older engines tend to consume more and reduce interest in use as well as reprocessing of parts to repair (Aircraft Commerce, 2018). However, although there is a massive increase in new-generation aircrafts and engines, there is still a demand, for the time being, the repair and overhaul of older engines such as the Pratt & Whitney JT8D-200; PW JT9D, PW2000, PW4000-94, Rolls-Royce RB211-535, CFM56-3 and -5 series GE CF6-50 and -80C2 (Aircraft Commerce, 2018). As the new-generation engines have come online, OEMs have increased their presence in the maintenance repair and overhaul (MRO) market (Aircraft Commerce, 2009). Also, many of the major maintenance providers for the older engine types leave the market in favor of pursuing the maintenance market for younger engines (Aircraft Commerce, 2018).

OEMs that undertook MRO services did so in a big way, with engine shops all over the world. It is fair to say that at least 30% of the global engine shops are a joint venture in some way with engine manufacturers (Aircraft Commerce, 2009). A few major airlines still have their shops for overhauling engines, such as Lufthansa, Air

France Industries, Delta TechOps, and United Services. These airlines have developed in-house repair and overhaul capability for all or most of the engine types in their fleets and offer their maintenance, repair, and overhaul (MRO) services to other operators(Aircraft Commerce, 2014).

Not only do some have a main shop at their base, but a few also have diversified into other continents. Lufthansa, for example, through JVs and wholly-owned subsidiaries, has many engine shops in Europe, Asia Pacific, and North America. About 50% of the global engine shops are connected to an airline. About 75% of global engine shops are connected to either an airline or an OEM. Some, such as TAESL and HAESL, are connected to both. This leaves just a quarter of engine shops in independent hands. The largest of these independent companies include MTU Maintenance, ST Aerospace, and SR Technics, all of which have invested in facilities on three continents. (Aircraft Commerce, 2009).

Research by Oliver Wyman shows OEMS 53% of engine maintenance services are always the same companies that did them, Chandler, J. G. (2018, 03).

Although there are a few independent engine MROs in the world, they still depend on OEMs for the delivery of parts to be installed on the engines repaired at their facilities.

One important consideration is that although the number of engine MROs globally in quantity may seem to be high, very few of them are capable of repairing several different engine types. Figure 5 below illustrates the main engine MROs in the world capable of overhauling the CFM56-7. This picture helps to understand that Brazilian airlines do not count on a privileged position for repairing their engines. Brazil counts with just one MRO in-country, located in Petropolis - RJ. As a result, depending on the type of engine which needs repair, it needs to be done abroad.

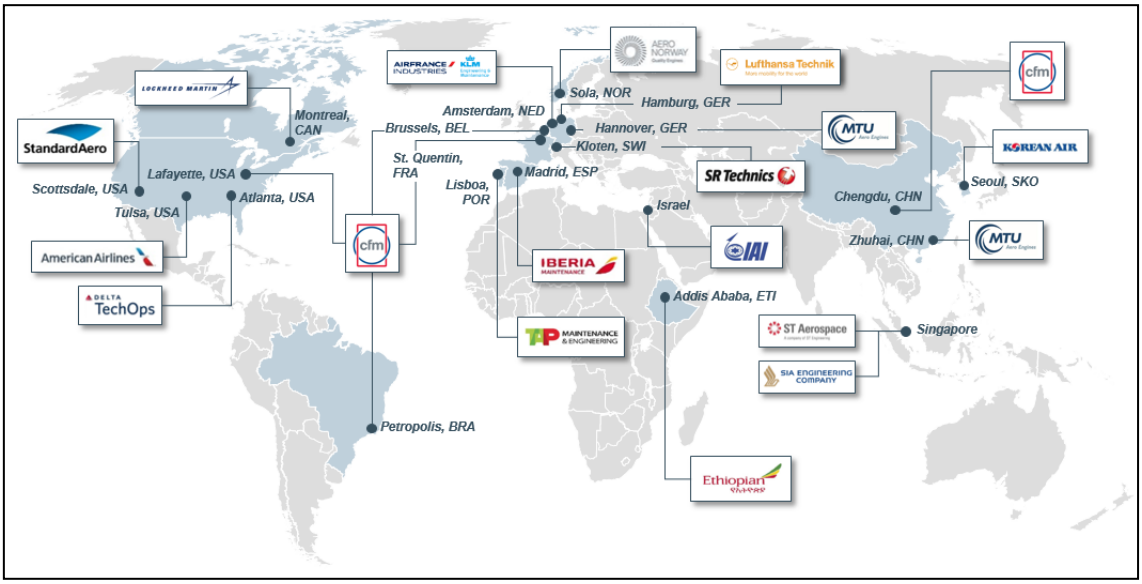

Figure 5. CFM56-7 main MROs, retrieved from MROs website.

Another point that deserves attention is that even if an airline opts to repair its engine in Brazil, its repair cost will be dollarized. As a result, Brazilian airlines need to take into account currency exchange fluctuations.

Brazilian Current Exchange

Global economic forces - such as interest rates in the United States and European Union (Eidelchtein, 2009) - and internal politics uncertainties - such as politics succession perspectives, difficulties to approve economic reforms, taxes condition (Eidelchtein, 2009) - are the main drivers for the influx and outflux of dollars to and from Brazil. These forces cause the Brazilian currency to fluctuate. Based on the numbers extracted from Domestic Airfares 1st Quarter 2019. (ANAC, 2019) And Brazil Central Bank (Banco Central do Brasil, 2019) we can observe in figure 6 significant variations on current Brazilian exchange along the past five years. In practical terms, if an engine repair that was done in September 2014 were to be done in September 2019, it would cost 77% more.

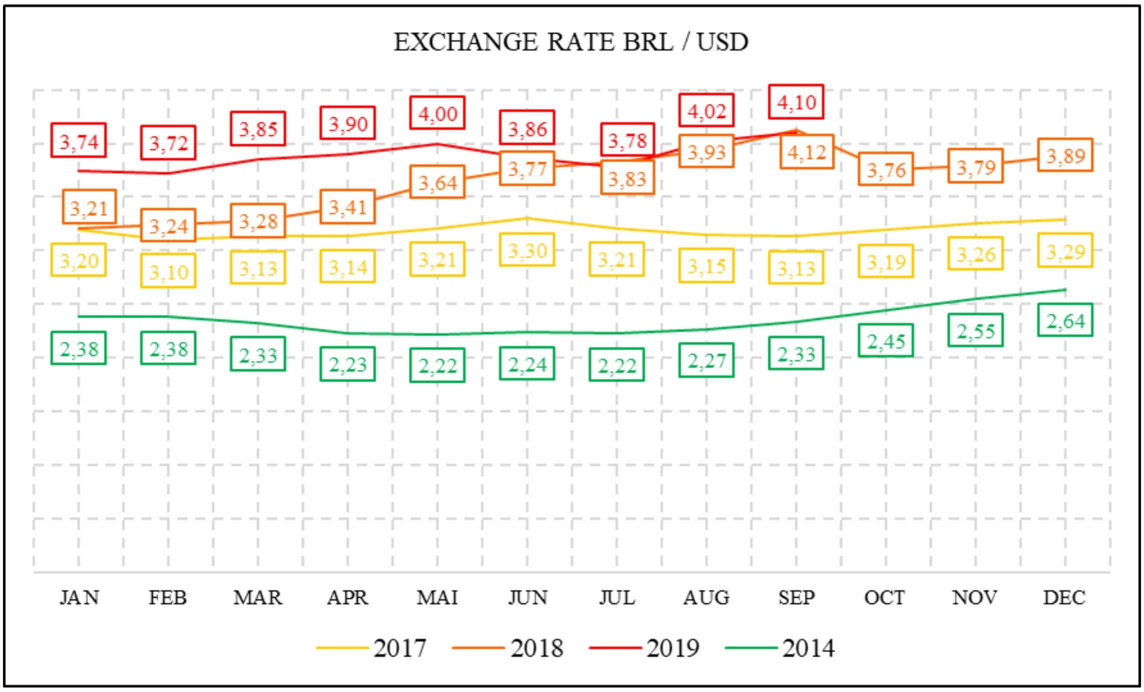

Figure 6. BRL / USD exchange rate, ANAC (2019) and Brazil Central Bank.

Engine Maintenance Cost

In order to provide aviation mechanism indicators worldwide, IATA (MCTF) collects data and all companies around the world annually and methodologically to define how much it costs for an airline to maintain its fleet for decision-making.

In 2017 global spending on MROS was $ 76 billion, disregarding general costs.

That means 11% of companies' operating costs.

Estimating an annual increase of 4% per year, this could reach $ 118 billion by 2027.

See Figure 7 below for global MRO spending in 2017 by segment and Figure 8 for expected global MRO spending in 2017 by segment.

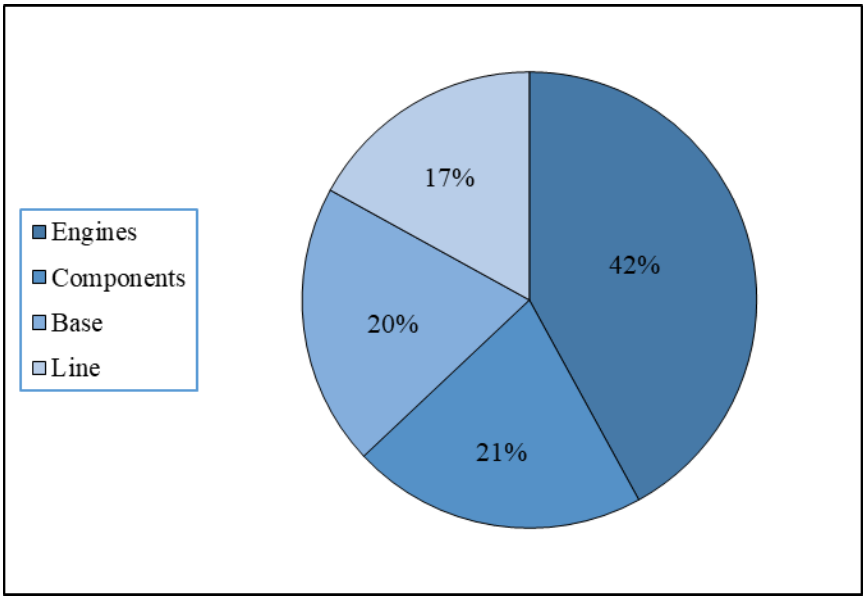

Figure 7. 2017 World MRO Spend by Segment. Adapted from IATA 2017 Maintenance Cost Task Force

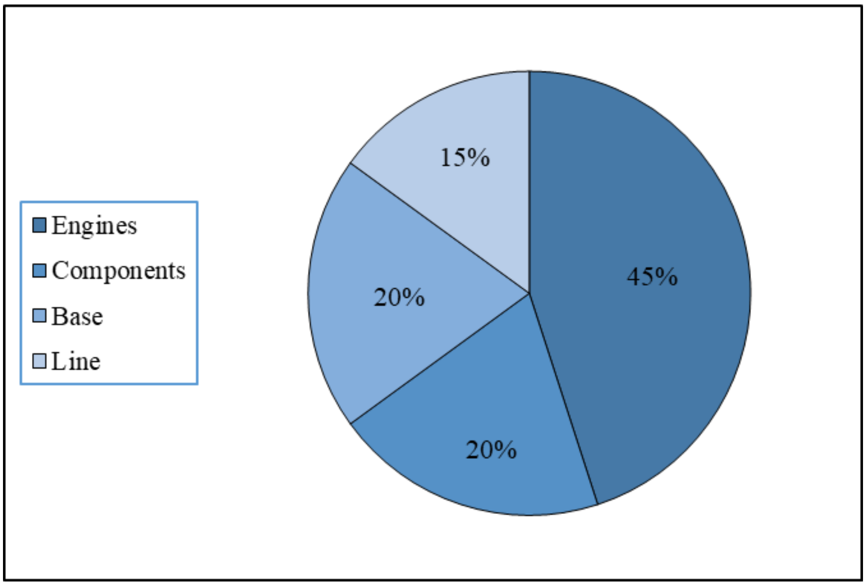

Figure 8. 2027 Projected World MRO Spend by Segment. Adapted from IATA 2017 Maintenance Cost Task Force

By observation of both figures, it can be seen that engine maintenance is the most relevant MRO account and tends to be even more relevant in the future.

Customs Clearance, Import, Export

The management of customs activities, the monitoring, control, and taxation of foreign trade in Brazil is ruled by law decree 6.759 from February 5th, 2009. This law decree is signed by the Brazilian president and issued by Ministério da Casa Civel (Civil House

Ministry). The document provides all instructions and references for all kinds of foreign trade allowed to be done in Brazil.

An important governmental institution which heavily participates in the import and export of goods in Brazil is Receita Federal do Brazil (RFB). Receita Federal is responsible for the administration of federal taxes and customs control and acts to combat tax evasion (smuggling), embezzlement, piracy and drug, and animal trafficking.

After complying with the legal and commercial requirements of the country in force, any operation is defined by importation, whether it facilitates the entry of goods into a customs territory or not. (Assumpção, 2007).

The import and export are done through Siscomex, an integrated and information system used by customs to receive all the data related to the goods to be imported and exported. Siscomex was created by law decree 660 from September 25th, 1992, to register, follow up, and control through a single flow of information the import and export processes (Eidelchtein, 2009). The system is managed by the Foreign Trade Secretariat of the Ministry of Industrial Development and Trade (MDIC / SECEX), the Central Bank of Brazil and the Federal Revenue Secretariat of the Ministry of Finance (MF / SRF), in their responsible areas of activity, respectively commercial, foreign exchange and tax. (Faro, 2007). The importation is the moment that configures the release of the goods; it is the established place for delivery of documents that must be presented with established deadlines. (Gama, 2013). Imports into Siscomex are processed in several stages to be performed by the importer, the depositary, the customs inspection, and the carrier.

It is the responsibility of the international maritime carrier, in the Siscomex Cargo module, to provide RFB with information about the vehicle and the domestic, foreign, and transit cargo carried therein, for each call of the vessel in a customs port. In the case of air modal, the electronic manifest must be informed in the Mantra system. The depositary is responsible for immediately informing the RFB of the availability of the cargo collected in its custody. It is up to the importer to register the DI (Import Dispatch) or DSI (Simplified Import Dispatch) in the System. Once analyzed, Siscomex will identify the configuration channel where it will remain until it obtains the customs authority, if applicable. In this place, there are four surveillance channels; they are Red, Green, Yellow, and Gray. (Gama, 2013).

It is up to the customs control to check the customs and the clearance. Figure 9 illustrates not only the various dispatch steps but also other steps that are part of the import process

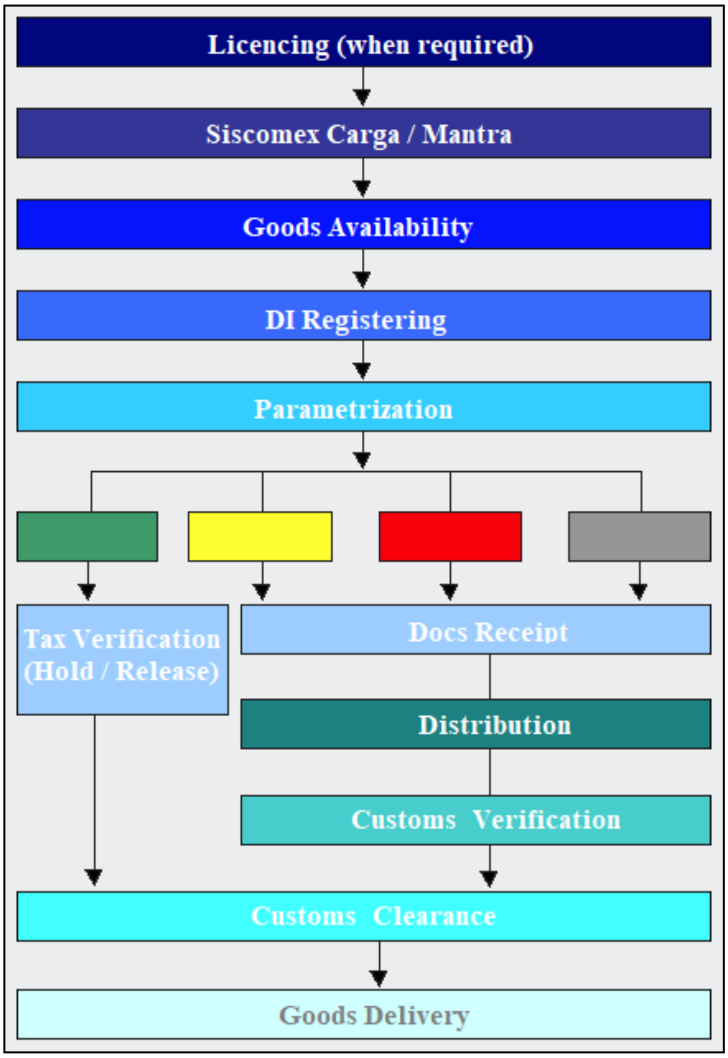

Figure 9 Import Dispatch. Adapted from RFB.

Below a brief description of the five possible parametrization channels:

Green: the system records the automatic clearance of the goods, exempting the documentary examination and the physical verification of the merchandise (RFB, 2014). The ID selected for the green channel in Siscomex may be subject to physical or documentary verification when evidence of import irregularities is identified by the RFB agent responsible for this activity (RFB, 2014);

Yellow: a documentary examination must be performed and, if no irregularity is found, the customs clearance has been made, and the physical verification of the goods is not required (RFB, 2014). In the event of incomplete description of the goods in the DI, which requires physical verification for their perfect identification to confirm the correctness of the tax classification or declared origin, the RFB agent may condition the conclusion of the documentary examination to the physical verification of the goods (RFB, 2014);

Red: the goods are only cleared after the documentary examination and physical verification of the goods (RFB, 2014);

Gray: the documentary examination, the physical verification of the merchandise, and the application of a special customs control procedure should be performed to verify signs of fraud, including the declared price of the merchandise (RFB, 2014).

Unfortunately, import and export processes in Brazil are occasionally impacted by frequent strikes, which bring substantial losses to the Brazilian industry and increase the risks to do business with the country. Most of the time government agents halt their work for undetermined periods claiming better salaries and benefits. As an example, the last strike initiated in November 2017 and endured until late July early August 2018, the estimated losses are around BRL 10 million per day (Terra, 2018). As a result of strikes, the import and export of goods, including engines, take longer than usual, increasing their turnaround time.

Homologation

The legal obligations and certification documents for a maintenance organization under EASA and FAA regulations are broadly RBAC 145 (ANAC) and FAR 145 (FAA) regulations. Among these documents there are no significant differences as RBAC 145 is broadly a translation of FAR 145 into Portuguese. For the approval of a workshop, the approval steps are divided into 5 phases:

1. Certification Contents of the IS (Supplementary Instruction - IS 145.001 (d)) document especially the section between sections 5.1 and 5.5 that describes all the steps from the preparation of the initial certification request to the issuance of the certificate / operative specifications.

Note: I did not find a FAA document with similar content.

2. Training: Contents of the IS (Supplementary Instruction - IS 145.010) document (a) especially sections 5.2.1 (a), 5.2.5 (c) and the passage between sections 5.2.5 (a) to (e) which describe the types of training required and how to design a Maintenance Organization Training Program.The FAA has a document called.

AC 145-10 - Repair Station Training Program that presents concepts similar to those described in ANAC IS.

3. Tools: Contents of the IS (Supplementary Instruction - IS 145.009 (b)) document especially the section between sections 5.5.2.1 (c) through (e) describing how an organization should demonstrate the ability to perform maintenance services based on tools that you have or have access to. The FAA has a document called.

AC 145-9A - Guide for Developing and Evaluating RS / QCM that features virtually the same content as ANAC IS

4. Manufacturers own releases and etc.

For all purposes a release from the article manufacturer is not required for a Maintenance Organization to perform maintenance on it, but in practice in accordance with IS (Supplementary Instruction - IS 145.109-001 (c) a Maintenance Organization is required to prove which has access to the technical data issued by the manufacturer of the article to be maintained either by contract with the manufacturer itself or by assignment by the owner or operator of the article (ref .: sections 5.3, 5.4 and 5.5 of the document).

Summary

Any manufactured product or system is subject to a certain level of perfection, which satisfies its design intent. As time passes, the product or system deteriorates to inferior levels of perfection, which if not restored to its original design intent, may cause loss to their users, owners or society. Aircraft engines are also subject to these same principles, and their design intent is preserved through scheduled and unscheduled maintenance. Both scheduled and unscheduled maintenances are aimed at keeping or returning the engine to its serviceable condition, therefore, assuring its safety to operators and society. These maintenance events are performed in specialized repair shops certified for specific engine types under the surveillance of regulators in a controlled environment. As a result, few organizations in the world have financial strength and count with the adequate capability for repairing engines. It is not rare joint ventures between airlines and engine manufacturers to build engine repair shops. Engine repair costs are dollarized and the most relevant maintenance cost for airlines. Brazil has just one engine repair shop in the country, which drives airlines to send engines to be repaired globally. Brazilian currency exchange rates fluctuation and uncertainty on the import-export process may bring additional challenges to local airlines.

Chapter III
Methodology

This section brings the resources used for evaluating the viability of having a particular repair for a particular engine being performed in house. Considering that airlines have particular engine fleets and operating conditions, airlines shall adopt this methodology to their condition. As already mentioned in the previous chapters, the ultimate goal of this study is to provide airline insights about how to reduce operational costs by increasing its internal capability for repairing engines. Whatever the possibility of reducing maintenance costs, it always brings more opportunities to an airline. (Fritzsche et al., 2014).

As an airline runs, it accumulates historical data about its fleet. This historical data encompasses operational as well as maintenance records. Typical operational data for the engines comprise EGT, flight cycles, flight hours, fuel consumption, oil consumption, and vibration level. Typical maintenance data comprises repair records, maintenance check records, among others. From time to time, airlines can benefit from reviewing their historical data as valuable information may be extracted. If carefully reviewed, this historical data may allow good decision-making for processes improvements and cost reduction.

A group of engineers, by analyzing engine maintenance history, identified a repair, which was a potential opportunity to be internalized. There were 12 repairs understudy done in the last four years resulting in an average of 4 repairs per year. Evaluation of the engine fleet condition indicated that at least 15 repairs should be done in the next five years as a minimum. The study, among other things, focused on alternatives to improve the engine turnaround time, therefore, enabling the engine to be available for longer periods. This shorter turnaround time may, in the long run, reduce the company´s spare engines and consequently, the operational cost. To better understand the challenges that the repair presents if done in house, the engineers visited a specialized MRO and watched all the details involved in the repair process. During the visit to the MRO, they could better evaluate all the tooling required, workforce, as well as the risks involved in the operation. The resulting analysis was split into two: one to evaluate the turnaround time and others to evaluate the costs involved in the repair. The Data Source, Collection, and Analysis below bring details about the resulting analysis.

Data Source, Collection, and Analysis

Turnaround Time, Costs and Associated Expenses for External Repair

The repair understudy, when done in a specialized MRO, based on historical records, is, on average accomplished in 21 calendar days. However, often, due to MRO capacity, the engines need to wait a few days to be inducted and have its repair initiated. Although there are variations in the queuing time, on average, an engine needs to wait around 33 calendar days to be inducted. The time an engine needs to wait to be inducted is undesirable because it extends the period under which the engine is unserviceable. A typical turnaround time for sending an engine to be repaired abroad (United States or Europe) is, on average 18 for export and 17 for the import processes under normal circumstances. It is important to remember, however, that import and export processes may suffer extensions from 10 to 15 days during periods when the Brazilian customs are on strikes. Figure 10 below illustrates the entire repair process for a typical engine.

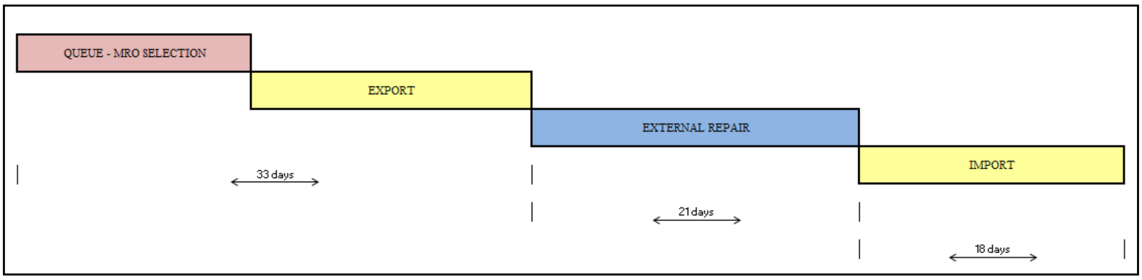

Figura 10 Repair Cycle Turnaround Time

Historical records show that the repair understudy costs, on average, USD 94.419,48 for labor and USD 203.375,08 for material, totalizing USD 297.794,56. Logistic, on average, accounts for USD 12.500,00 on the export phase and USD 17.500,00 on the import phase. It is important to highlight that values for logistics vary significantly depending on the volume and weight of the transported product. As a result, due to the different engines on the market transportation costs vary significantly due to its size and weight differences. Another aspect to be considered when evaluating transportation costs is the volume of goods to be transported under a certain contract. Usually the higher the volume under the transportation contract, the higher the chances to do a better deal. Additional expenses involved in the export and import processes, such as storage of the goods during custom clearance, fees, and customs broker as well as corresponding taxes to accomplish the operation, are shown in Table 5 below. No insurance was hired to transport the engines because they are under the overall airline insurance. However, it represents a high cost and shall be considered for evaluating the repair viability if applicable:

Table 6

Repair costs and associated expenses (BRL):

Export		Import	
Custom Broker	1.388,72	Customs Broker	1781,42
Insurance	0,00	Insurance	0,00
Freight	49.000,00	Freight	68.600,00
Fees	244,00	Fees	244,00
Storage	3.871,92	Storage	4.780,96
		Material	**797.230,32**
		Tax - COFINS	7.972,30
		Tax - ICMS	35.539,84
		Labor	**370.124,36**
		Tax - ICMS	16.499,82
		Tax - IRRF	65.316,22
		Tax - CIDE	43.545,13
Total Export	54.504,64	Total Import	1.411.634,38
Total Export & Import			1.466.139,02

Turnaround Time and Costs Internal Repair

The careful study of the engine and aircraft manual plus the visit to the specialized MRO enabled the engineers to identify all the steps involved in the process, the corresponding tooling necessary to do the job, the adequate personnel to do the job, the expected turnaround time to accomplish the repair in house and the risks involved in the operation. One important observation is that due to the complexity of the repair process, it is expected that the mechanics shall pass through a learning curve to achieve enough familiarization and expertise to be able to perform the repair as fast as a specialized MRO. The first repairs to be done in house are estimated to be accomplished around 50 days (more than twice than a specialized MRO). As time passes and the mechanics accumulate experience, this number decreases and establishes around 28 days (seven days longer than a specialized MRO). The learning curve, as well as a comparison between the time it takes to perform the repair in an external MRO and internally, can be observed in Table 7 below:

Table 7

Comparison for Turnaround Time in days between external repair and internal repair:

Year	Repair #	External Repair				Internal Repair	Saving
		Export + Queue	Repair	Import	Total	Repair	
1	1	33	21	17	71	50	21

1	2	33	21	17	71	50	21
1	3	33	21	17	71	46	25
2	4	33	21	17	71	46	25
2	5	33	21	17	71	42	29
2	6	33	21	17	71	42	29
3	7	33	21	17	71	38	33
3	8	33	21	17	71	38	33
3	9	33	21	17	71	34	37
4	10	33	21	17	71	34	37
4	11	33	21	17	71	30	41
4	12	33	21	17	71	30	41
5	13	33	21	17	71	28	43
5	14	33	21	17	71	28	43
5	15	33	21	17	71	28	43
Total =	15	495	315	255	1065	564	501

The investment in material resources (fixtures and dedicated tooling) is USD 1.051.360,68. The facility (rent, electricity, etc.) costs are BRL 28.350,00 per month. The proposed headcount for a local repair shop is one supervisor, two lead mechanics, and two senior mechanics. An estimating cost for human resources is BRL 81.242,28 per month. The training to certify the personnel to do the job is USD 89.000,00. It is important to highlight that this study considered the average exchange rate that occurred from January 1st, 2019 to October 13th, 2019 (1 USD = BRL 3,92) provided by Banco Central do Brasil (BACEN, 2019).

Based on the projected values for the length of an internal repair, it was possible to estimate its labor cost. Considering that it will be performed in 50 days, its cost will be the daily labor rate multiplied by the number of days it takes. As a result, the labor cost for the first repair is BRL 135.403,80. Material costs do not change once the replacement parts are all the same and supplied by the engine OEM. Table 7 shows the costs for the first repair done in the house. One important observation is that according to Brazilian regulation IN RFB N1700 March 14, 2017, the total investment in tooling may be depreciated within five years.

Table 8

Cost (BRL) for internal repair:

Export		Import	
Custom Broker		Custom Broker	
Insurance		Insurance	
Freight		Freight	
Fees		Fees	
Storage		Storage	
		Material	**797.230,32**
		Tax - COFINS	7.972,30
		Tax - ICMS	35.539,84
		Labor	**135.403,80**
		Tax - ICMS	
		Tax - IRRF	
		Tax - CIDE	
Total Export	0,00	Total Import	976.146,27
Total Export & Import			976.146,27

Chapter IV
Outcomes

We can observe from table 6 that the external repair cost (797.230,32 + 370.124,36 = 1.167.354,69) is increased (to 1.466.139,02) by 25,6% due to associated expenses related to the import and export process as well as the taxes incurred. We can also observe by comparing Tables 6 and 7 that the internal repair cost for the first repair (BRL 976.146,27) is significantly lower (33%) than the external repair cost (BRL 1.466.139,02). To better visualize the cost differences, table 6 and 7 are reproduced in figure 11 below.

External Repair

Export		Import	
Custom Broker	1.388,72	Customs Broker	1781,42
Insurance	0,00	Insurance	0,00
Freight	49.000,00	Freight	68.600,00
Fees	244,00	Fees	244,00
Storage	3.871,92	Storage	4.780,96
		Material	**797.230,32**
		Tax - COFINS	7.972,30
		Tax - ICMS	35.539,84
		Labor	**370.124,36**
		Tax - ICMS	16.499,82
		Tax - IRRF	65.316,22
		Tax - CIDE	43.545,13
Total Export	54.504,64	Total Import	1.411.634,38
Total Export & Import			1.466.139,02

Internal Repair

Export		Import	
Custom Broker		Custom Broker	
Insurance		Insurance	
Freight		Freight	
Fees		Fees	
Storage		Storage	
		Material	**797.230,32**
		Tax - COFINS	7.972,30
		Tax - ICMS	35.539,84
		Labor	**135.403,80**
		Tax - ICMS	
		Tax - IRRF	
		Tax - CIDE	
Total Export	0,00	Total Import	976.146,27
Total Export & Import			976.146,27

Figura 11 Cost comparison between External and Internal Repair

This lower cost for the first repair tends to be even lower as time passes, and the team gains experience to execute it. The cost reduction between internal and external repair is the result of a lower cost of manpower, no expenses for logistics and lower incurrence of taxes.

Although there are indications that the repair in house is more economically attractive, a deeper study is necessary to confirm if all the required investment is worth it. This study comprises evaluating the cash flow for both scenarios, internal and external repair, in the next five years, considering the expected volume of work to be accomplished per year. Another very important point to be taken into account is the economic adjustments that need to be projected in the future, considering inflation for the several sectors involved in the repair process, current exchange, interest rates, and all the incurred costs or expenses along the period. Values for the currency exchange rate and inflation (IPCA) for the next five years are based on projections made by Banco Central do Brasil (BACEN, 2019). Material and labor escalation is based on industry practices. Custom broker and fees, due to a conservative approach, are considered unaltered throughout the period. The result of the analysis can be seen in tables 9 and 10 below.

Table 9

Cash flow (BRL) for external repair next five years:

	Year	IPCA	USD	Investment / Rent	Customs Broker	Insurance	Freight	Fee	Storage	Material (6,5%)	Tax - COFINS	Tax - ICMS	Labor (3,5%)	Tax - ICMS	Tax - IRRF	Tax - CIDE	Cash Flow / Repair	Cash Flow / Year
IMPORT	1	4,96%	3,92	0,00	1.781,42	0,00	68.600,00	244,00	4.780,96	797.230,32	7.972,30	35.539,84	370.124,36	16.499,82	65.316,22	43.545,13	1.411.634,38	4.234.903,14
	2	6,37%	3,94	0,00	1.781,42	0,00	68.950,00	244,00	4.780,96	853.382,19	8.533,82	37.587,86	385.033,20	17.450,64	67.947,19	45.299,16	1.490.990,44	4.472.971,32
	3	3,18%	3,92	0,00	1.781,42	0,00	68.600,00	244,00	4.780,96	904.238,57	9.042,39	39.365,44	396.486,47	18.275,91	69.968,36	46.646,63	1.559.430,14	4.678.290,43
	4	3,18%	3,96	0,00	1.781,42	0,00	69.300,00	244,00	4.780,96	972.840,75	9.728,41	41.871,04	414.550,88	19.439,17	73.156,21	48.771,91	1.656.464,74	4.969.394,21
	5	3,18%	4,02	0,00	1.781,42	0,00	70.350,00	244,00	4.780,96	1.051.773,51	10.517,74	44.767,33	435.561,07	20.783,81	76.863,90	51.243,76	1.768.667,49	5.306.002,46
EXPORT	Year	IPCA	USD	Investment / Rent	Customs Broker	Insurance	Freight	Fee	Storage	Material (6,5%)	Tax - COFINS	Tax - ICMS	Labor (3,5%)	Tax - ICMS	Tax - IRRF	Tax - CIDE	Cash Flow / Repair	Cash Flow / Year
	1	4,96%	3,92	0,00	1.388,72	0,00	49.000,00	244,00	3.871,92								54.504,64	163.513,91
	2	6,37%	3,94	0,00	1.388,72	0,00	49.250,00	244,00	3.871,92								54.754,64	164.263,91
	3	3,18%	3,92	0,00	1.388,72	0,00	49.000,00	244,00	3.871,92								54.504,64	163.513,91
	4	3,18%	3,96	0,00	1.388,72	0,00	49.500,00	244,00	3.871,92								55.004,64	165.013,91
	5	3,18%	4,02	0,00	1.388,72	0,00	50.250,00	244,00	3.871,92								55.754,64	167.263,91
EXPORT + IMPORT	Year	IPCA	USD	Investment / Rent	Customs Broker	Insurance	Freight	Fee	Storage	Material (6,5%)	Tax - COFINS	Tax - ICMS	Labor (3,5%)	Tax - ICMS	Tax - IRRF	Tax - CIDE	Cash Flow / Repair	Cash Flow / Year
	1																	4.398.417,05
	2																	4.637.235,23
	3																	4.841.804,35
	4																	5.134.408,12
	5																	5.473.266,37

Table 10

Cash flow (BRL) for internal repair next 5 years:

	Year	IPCA	USD	Investment / Rent	Customs Broker	Insurance	Freight	Fee	Storage	Material (6,5%)	Tax - COFINS	Tax - ICMS	Labor (IPCA)	Tax - ICMS	Tax - IRRF	Tax - CIDE	Cash Flow / Repair	Cash Flow / Year
INTERNAL	1	4,96%	3,92	4.810.213,87	0,00	0,00	0,00	0,00	0,00	797.230,32	7.972,30	35.539,84	131.793,03	0,00	0,00	0,00	972.535,50	7.727.820,37
	2	6,37%	3,94	356.864,00	0,00	0,00	0,00	0,00	0,00	853.382,19	8.533,82	37.587,86	123.170,52	0,00	0,00	0,00	1.022.674,39	3.424.887,16
	3	3,18%	3,92	379.596,24	0,00	0,00	0,00	0,00	0,00	904.238,57	9.042,39	39.365,44	105.621,29	0,00	0,00	0,00	1.058.267,68	3.554.399,27
	4	3,18%	3,96	391.667,40	0,00	0,00	0,00	0,00	0,00	972.840,75	9.728,41	41.871,04	87.551,37	0,00	0,00	0,00	1.111.991,57	3.727.642,11
	5	3,18%	4,02	404.122,42	0,00	0,00	0,00	0,00	0,00	1.051.773,51	10.517,74	44.767,33	78.237,40	0,00	0,00	0,00	1.185.295,97	3.960.010,33

A better visualization of the numbers from Tables 9 and 10 can be seen in figures 12 and 13.

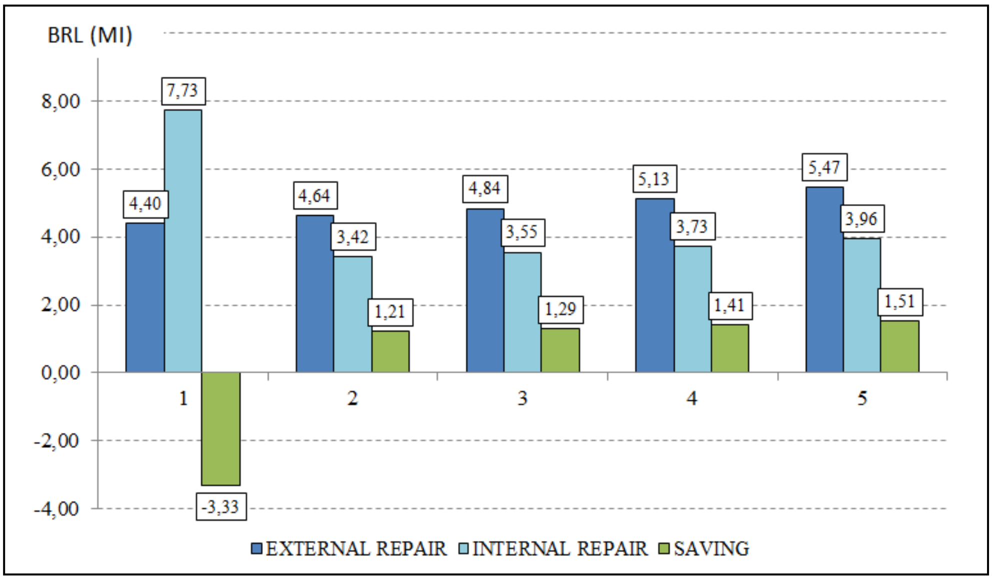

Figura 12 Cash flow for External and Internal Repair.

The net present value of the accumulated savings of each year, as well as the total net present value for the entire period of 5 years, can be seen in figure 13 below:

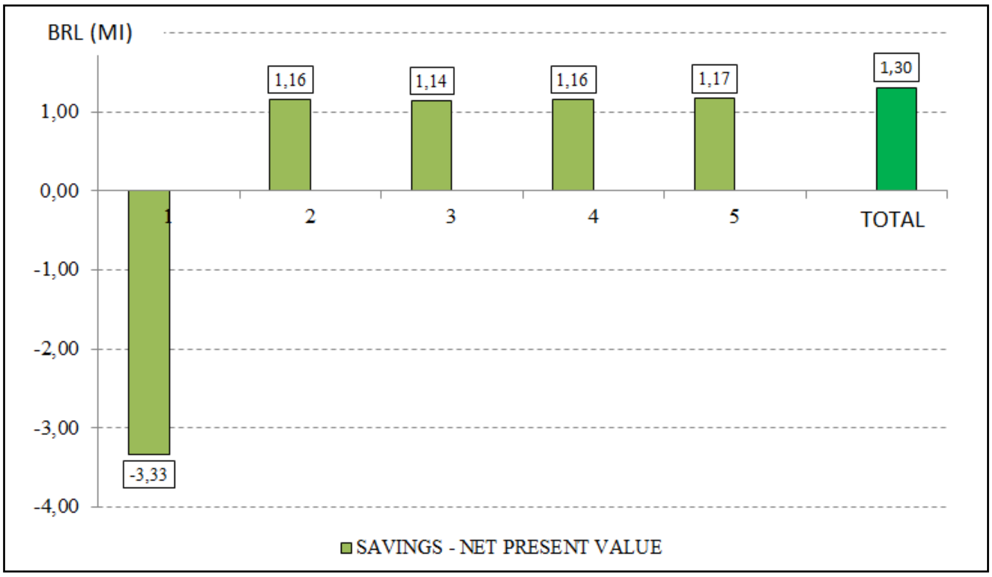

Figure 13 Net Present Value for Accumulated Savings.

By comparing both cash flows, we confirm that if the repair is internalized the airline may have a saving BRL 1.3 million.

Table 10
Net present value (BRL) for accumulated saving the next five years if the repair is internalized:

External Repair - Cash Flow / Year	Internal Repair - Cash Flow / Year	Saving	Discount Rate	NPV
4.398.417,05	7.727.820,37	-3.329.403,31	5,91%	-3.329.403,31
4.637.235,23	3.424.887,16	1.212.348,07	4,82%	1.156.599,95
4.841.804,35	3.554.399,27	1.287.405,08	6,16%	1.142.334,78
5.134.408,12	3.727.642,11	1.406.766,02	6,61%	1.160.988,82
5.473.266,37	3.960.010,33	1.513.256,03	6,66%	1.169.246,55
	Total =			1.299.766,78

Apart from financial gains, the airline may benefit due to the shorter turnaround time for the repair process. This can be seen in figure 14 below.

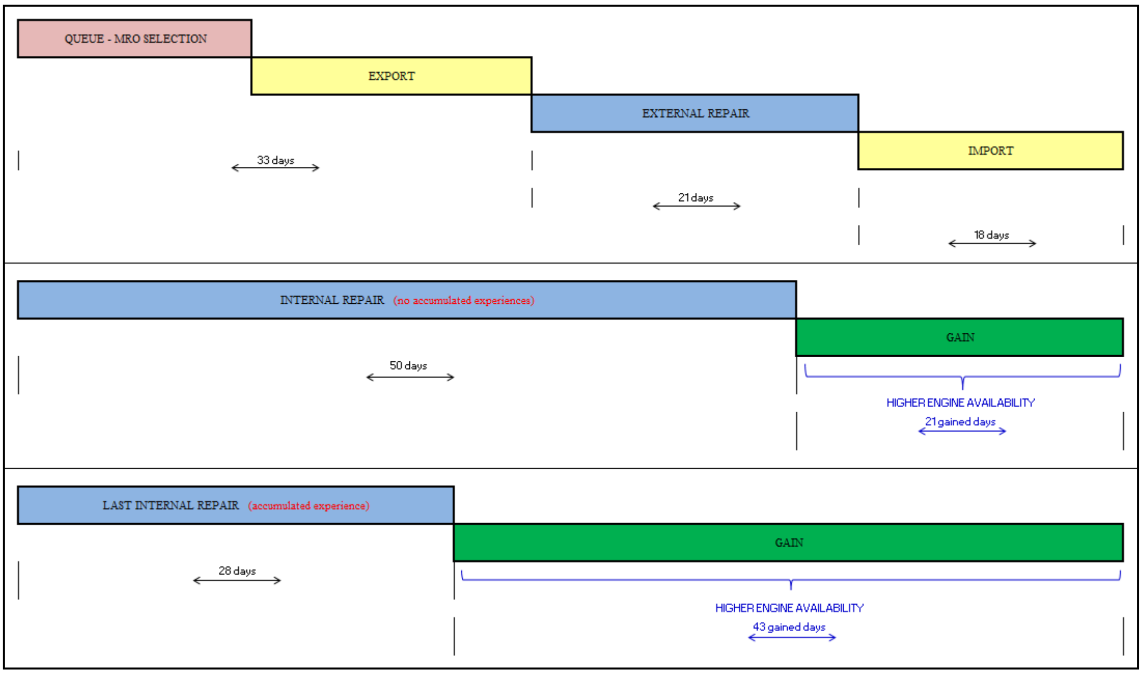

Figura 14 Turnaround time saving due to internal repair.

Chapter V
Conclusions and Recommendations

Conclusions:

The effort for evaluating if airlines can benefit from internalizing repair was, the internalization of a light repair is a very strategic choice for any Brazilian airline. If properly evaluated, it can provide financial as well as operational gains.

Recommendations

Airlines shall evaluate its engine repair fleet and historical data. By doing so, they can identify important cost reduction and operational gains.

Key Lesson Learned: Taxes play a very important role in engine repair. If internalized, substantial savings may be obtained.

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