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Financial Evaluation for a Brazilian Airline to Conduct Aeronautical Components Repair in Brazil

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by

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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 Certificate Program

Capstone Project Chair:

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Dr. Leila Halawi
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Date

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Abstract

Group: Maintenance Optimization Team

Title: Financial Evaluation for a Brazilian Airline to conduct aeronautical components repair in Brazil

Institution: Embry-Riddle Aeronautical University

Year: 2018

The current economic world volatility, as well as the increasing cost of fuel and security procedures established by the worldwide authorities, force the air carriers to search for alternatives to reduce their operational costs. The maintenance costs are a significant subject for the air carriers, therefore, any cost reduction obtained without maintenance service disruption, may provide an opportunity to enhance the airline competitiveness (Fritzsche, 2014).

The purpose of this research is to evaluate and compare the technical and financial aspects of performing aircraft components repair in house for a Brazilian airline versus outsourcing the servicing to a homologated company outside the country.

In addition, this research will analyze the main challenges involved, such as costs involving the labor force, advantages and disadvantages of conducting the repair internally, the currency exchange and bureaucratic process applied by the Brazilian Customs to export and import components and opportunities along with companies classified as partners.

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Chapter I

Introduction

According to Vieira (2016), the maintenance represents around 11% of the variable operating cost of any air carrier.

In civil aviation, aircraft maintenance is a complex activity conducted by the airline technical specialists and this process usually occurs in the airports ramp areas, hangars and shops. These designated areas provide the space and the infrastructure needed to conduct the inspections, repairs and overhaul which would result in releasing the aircraft to operations

The direct maintenance costs refer to labor and materials spent on technical services performed by the mechanics in the aircrafts and in the components. Components maintenance costs in 2014 comprised 24% of the airline´s direct maintenance costs per flight hour (IATA, 2015). Considering the period from 2010 up to 2014, the average cost per flight hour, increased by 25% (IATA, 2015).

Project Definition

This research analyzes the technical and financial viability for a Brazilian air carrier to expand its actual components repair capability using its own Maintenance, Repair and Overhaul (MRO) facility. The goal is to use its current structure and specialized maintenance personnel to develop in house new repair capabilities and compare the advantages and disadvantages with outsourcing to a repair station outside the country.

With respect to the current procedure applied by the Air Carriers in Brazil, some of the entire aeronautical components are usually sent overseas to conduct such repairs.

The process has to strictly follow the Brazilian Customs export and import administrative requirements that includes effective and active communication between importers and exporters, and documentation filled out properly. Any discrepancy identified by the customs authorities during the import or export process can cause a significant delay in the release of aircraft´s components along with a significant effect on the reputation and resulting profit margins.

All evaluations of this research are based on a fictitious company named ABC Airlines that already provides components repair for the aircrafts manufactured by Airbus. ABC Company Services does not perform repair on engines nor auxiliary power units (APUs).

The Project Goals and Scope

The goal of this research is to identify opportunities to reduce costs to the Brazilian Air Carriers by conducting in house repairs of aeronautical components as opposed to outsourcing the repairs outside the country. It is expected to result in significant savings to the companies.

The scope of this project will cover different pillars, from costs involving maintenance workforce, to the advantages and disadvantages of internalizing components repairs, in addition to issues with the Brazilian customs and business opportunities between other Brazilian air carriers in Brazil.

Although the research is focused on the scenario of just one Brazilian air Carrier, the recommendations can be extended to other air carriers in Brazil with similar operational difficulties.

The research aimed to answer the following question: What is the best option to reduce maintenance costs and minimize operational disruption in service?

Definitions of Terms

ABEAR	¨Brazilian Association of Airlines, founded by Avianca, Azul, Gol and Latam, and also has associated companies like Latam Cargo, TAP Portugal, Bombardier and Boeing.¨ (AGENCIA ABEAR, 2017)
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)
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)
ICAO	¨The International Civil Aviation Organization (ICAO) is a UN specialized agency, established by States in 1944 to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention). ICAO works with the Convention´s 191 Member States and Industry groups to reach consensus on international civil aviation Standard and Recommended Practices (SARPS) and polices in support of a safe,

secure, economically sustainable and environmentally responsible civil aviation sector.¨ (icao.int, 2017).

List of Acronyms

ANAC	National Civil Aviation Agency
CMM	Component Maintenance Material
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
IATA	International Air Transportation Association
ICAO	International Civil Aviation Organization
MRO	Maintenance, Repair and Overhaul
NPV	Net Present Value
OEM	Original Equipment Manufacturer

Chapter II

Review of the Relevant Literature

In order to provide alternatives to reduce aeronautical components maintenance costs, the literature review was divided into three sections dealing with maintenance, repair and overhaul, maintenance costs and supply chain processes. The purpose of this division was (a) to explain the importance of a MRO and its services for the air carrier; (b) to present how relevant is the maintenance for the operation costs; (c) to understand the supply chain processes involved during imports and/or exports and (d) to analyze the costs of using outsourced services as opposed to insourcing.

Maintenance, Repair and Overhaul (MRO)

Maintenance operation is a very dynamic task with activities that can be segregated into a planned scheduled maintenance, which is a preventive service. On the other hand, there is an unscheduled maintenance, which can be classified as a service not planned due to a component or an item that has been failing or not working properly (Kinnisson, 2012). The maintenance and its continuous standard operation processes is crucial to maintain a high level of safety and reliability regarding the services involved (Kinnisson, 2012).

According to Vieira (2016), maintenance, Repair and Overhaul – MRO, is a process that involves retaining or restoring an item or a component, and therefore, maintaining its standard performance following the requirements stated by the Aeronautical Authorities. This process involves a combination of technical characteristics and administrative management activities.

During the maintenance process, if an equipment or a component presents any mechanical discrepancies, these parts should be removed from the aircraft and replaced with operative parts. Then, these parts removed are sent to the repair premises (Yoon, 1994).

The figure 2.1 illustrates the complex maintenance process that involves different type of MROs, considering four levels: Fully Integrated, Partially Outsourced, Mostly Outsourced and Wholly Outsourced.

Fully integrated MRO means the airlines performs all their maintenance activities internally (Al-Kaabi, 2007). Partially outsourced MRO means the airline conducts most of their maintenance needs internally and only the base maintenance inventory are outsourced (Al-Kaabi, 2007). Mostly outsourced MRO means the airline managed their line maintenance and engineering services and outsource all base maintenance activities (Al-Kaabi, 2007). Wholly outsourced MRO means the airlines outsources all the MRO activities except the engineering services (Al-Kaabi, 2007).

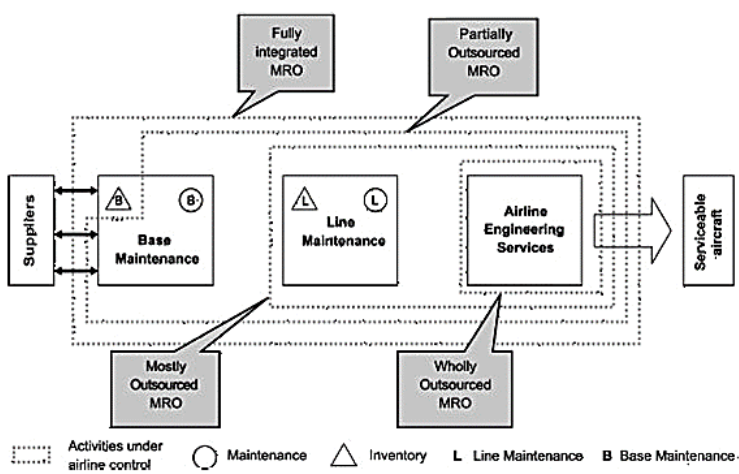

Figure 2.1. MRO Model Depictions. Adapted from “outsourcing decision model for airlines' MRO activities," by Al-Kaabi et al. 2007, *Journal of Quality in Maintenance Engineering*, 13(3). p. 200.

Commercial air carriers with MRO facilities use their own maintenance capabilities to conduct fleets repairs, as well as to provide services for other airlines, consequently increasing their profit margin. It is also common to see air carriers using their MROs as a separate corporate unit (Carpenter and Henderson, 2008).

Due the world aviation economic scenario complexity (such as currency exchange, political instability etc.), airlines had to reconsider their maintenance, repair and overhaul-MRO strategies in order to provide specialized and diversified services. This will also enables the repair facilities to be in conformity with their operational processes and to meet their financial targets (Miroux, 2012).

Insourcing and outsourcing. The reasons of whether or not to outsource repair components is an important and complex task and may influence a decision-making (Mclvor *et al.*, 1997),

The use of outsourcing components maintenance allows the airline to expand its capabilities and resources without expanding its workforce (Lewis, 1999).

In theory, some of the benefits of outsourcing is the flexibility, pay per use concept and low investments risks (Stapf, 2002). On the other hand, there are disadvantages that may appear such as partnerships with wrong suppliers, difficulties to monitor the contractor performance or unexpected costs (Staff, 2002).

In opposite to outsourcing, the airlines that have an MRO may use insourcing as a key factor of competitiveness to offer in-house different services to its own fleet as well as to third part customers (Červinka, 2012) .

However, to maintain sustainable and manageable insourcing option, important subjects, such as costs, quality, lead-times, inventory and labor must be aligned with the strategy and the goals of the company.

Maintenance Costs. According to Al-Kaabi (2007), the maintenance in the aeronautical industry deserves special attention since it is a high cost activity.

The International Air transportation Association – IATA (2015), predicts the MROs spending to reach $ 65 billion in 2020 as shown in figure 2.2

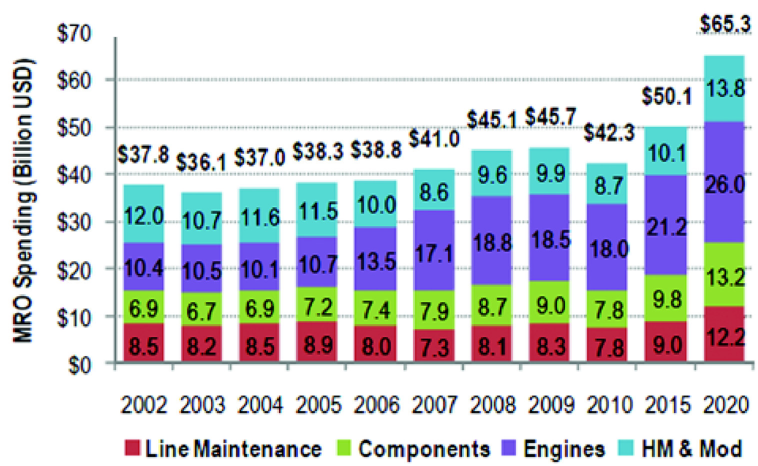

Figure 1.2. MRO spending forecast. Adapted from "Airline maintenance costs executive commentary" 2011, *International Air Transport Association*, p.3

Maintenance costs can range from 10% to 15% of the monthly operating costs (Samaranayake et al., 2002). These high costs are justified by the need for highly skilled labor and equipment involved, not to mention the high prices of the parts used in components or aircrafts (Samaranayake et al., 2002).

As obtained from the National Civil Aviation Agency (ANAC, 2018), the table 2.1 below describes the operation costs of the five main Brazilian Air Carriers, considering the amount of R$ 34.5 billion spent in 2017.

Table 2.1

Cost and expenses of Brazilian Air Transportation Adapted from "ANAC airfare rates," 2018, Department of Aviation ANAC, p, 3.

Description	**%**
Fuel and lubricants	27,5
Maintenance, rounding and insurances	20,3
People	17,4
Operating expenses	14,5
Miscellaneous costs	4,4
Navigation taxes	3,8
Ground handling	3,7
Depreciation	3,1
Passenger compensation	0,9
Judicial condemnation	0,9

Although all procedures and techniques applied on maintenance hardly changes, the maintenance costs are the opposite, and, consequently, it has been a considerable issue for airlines. Thus, due to the interest in trimming costs and reducing investments, more airlines are outsourcing MRO work rather than performing their own aircraft maintenance (Christopher, 2007).

Consequently, according to Christopher (2007), airlines maintenance outsourcing has been growing and the projection has an increased tendency, as demonstrated through table 2.2.

Table 2.2

MRO Outsourcing Adapted from “IBM Global Business Service," by Doan, 2007

Year	**%**
1990	30
2000	50
2020	70

Considering the costs with labor, it is common that air carriers shift their heavy maintenance using overseas providers. The figure 2.3 shows the airframe man hours rate comparing three countries. This information can assist to comprehend the impacts of labor in the maintenance costs.

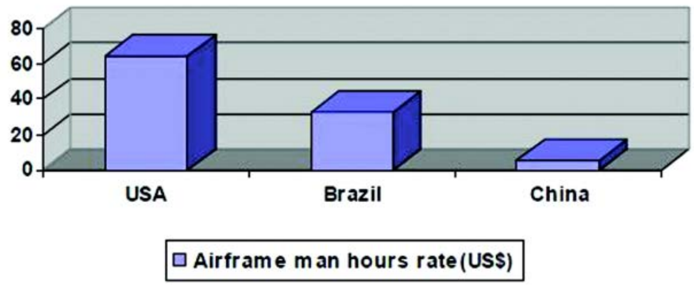

Figure 2.3. Estimated man hour costs in dollars. Adapted from "Test of MRO strategy for airlines," by Pandit, 2007. p. 6.

Supply Chain

Supply Chain is considered one of the most complex sectors in the aeronautical industry, as mentioned by Bales et al (2004).

These complexities vary from certification requirements up to the handling, and storage of the components.

Besides the maintenance documentation, which is very important to assure the quality and the safety for aircraft airworthiness, another relevant issue is the complex process to obtain the qualification and authorizations for the suppliers to provide maintenance services (Vieira, 2016). Due to this complexity, there are few certified companies (Vieira, 2016).

Some major suppliers decided to operate in different sub tiers and became suppliers of their competitors (Vieira, 2016). This scenario may affect negatively the relationship between them, and may affect the end-customers (Vieira, 2016).

In order to guarantee the safety and the aircraft airworthiness, FAA through the Part 145, established all regulatory requirements for Certified/non-certified repair stations.

Requirement	Certificated Repair Station	Non-Certificated Facility
FAA Inspections	Annual inspection required	No requirement
Quality Control System	Must establish and maintain a quality control system that ensures that repairs performed by the facility or a subcontractor are in compliance with regulations	No requirement
Reporting Failures, Malfunctions, and Defects	Must report failures, malfunctions, and defects to FAA within 96 hours of discovery	No requirement
Personnel	Must have designated supervisors, inspectors, and return-to-service personnel	No requirement
Training Program	Required starting April 2006	No requirement
Facilities and Housing	If authorized to perform airframe repairs, must have facilities large enough to house the aircraft they are authorized to repair	No requirement

Figure 2.4. *FAA Part 145 for Repair Stations and Non-Certificated Facilities. Adapted from "Air carriers' use of non-certificated repair facilities," 2005, Department of Transportation, p, 12.*

An important consideration punctuated by MacFadden (2012), was the total amount of money spending involved to keep inventory running, mainly regarding the intensive labor management involved. In addition, MacFadden said that this fact has been considered one important matter to take the decision regarding outsourcing or in-house maintenance.

Exchange Variation:

According to the Brazilian National Agency of Civil Aviation (ANAC) (June 29^{th,} the first quarter of 2018), the average exchange rate increased by 3.2% compared with

2017 and the average price of aviation kerosene increased by 18.5%. The exchange rate exerts a strong influence on aircraft fuel, maintenance and insurance costs, which together accounted for 49.6%, half of the costs and expenses of public air services of Brazilian companies.

According to figure 2.4, we can easily see the exchange rate of the Real against Dollar increased. Thus, due to the strong influence of the dollar, on fuel, rental, maintenance and aircraft insurance, together these expenses represented 50% of the costs of air service in the first quarter of 2018.

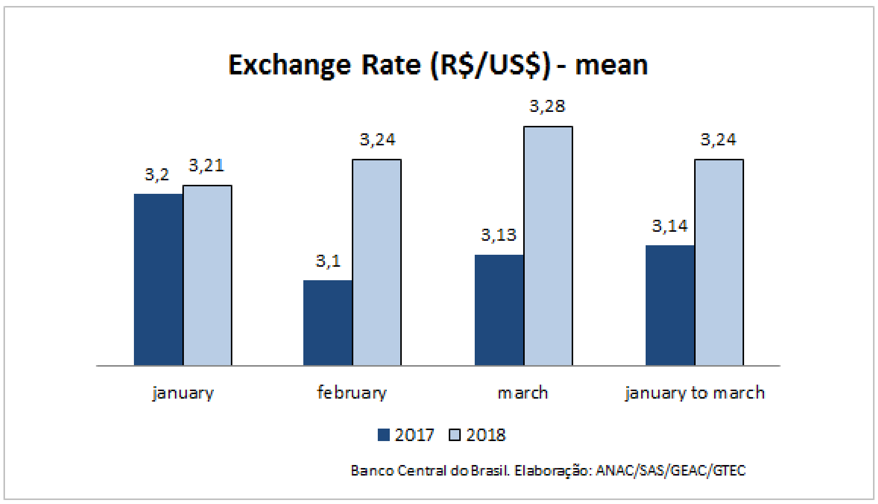

Figure 2.5. Exchange rate affecting Airline Maintenance. ANAC Annual domestic report airfare rates," 2018, Department of Transportation ANAC, p, 09.

Import Issues:

The import defines any operation that facilitates the entry of goods in a customs territory, after complying with the legal requirements and business (Assumpção, 2007).

The import configures at the time of merchandise clearance and takes place in pre-established locations with documents delivered at pre-established deadlines (Gama, 2013).

In Brazil, the import documents have to be launched into the customs system called Siscomex. Once analyzed, Siscomex will identity the parameterization channel, where it will remain until the conclusion by the customs authority, if applicable. There are four parameterization channels, namely: green, yellow, red and gray (Gama, 2013).

In the green channel, the Siscomex system will proceed to the automatic clearance of the merchandise (Assunpção, 2007).

In the yellow channel, the documentation examination is carried out, and if nothing irregular is found, the process will be cleared without the need to examine the commodity (Assunpção, 2007).

In the red channel, the merchandise will be cleared after the documentation is analyzed and a verification of its content is conducted (Assunpção, 2007).

In the gray channel, the clearance will only be made after the documentation examination, the verification of the merchandise and preliminary examination of the customs value (Assunpção, 2007).

Brazilian economic and political instability generate impacts for air carriers due to frequent sectors strikes. A governmental institution controls Brazilian customs and it is being subjected to several strikes along the last years. The impact is longer components turnaround time when repaired outside the country.

Summary

The operation of an airline requires aircrafts in safe and reliable condition. The number of flight cycles, flight hours, operating environment, crew operation standardization, fleet age and model of the aircraft are some of the elements that have a direct relation with aircraft maintenance frequency and costs. Aircraft operation results in natural degradation. Maintenance is applied to restore its intended function at its original level of reliability and safety.

Reducing maintenance cost in today's aviation industry is a necessary step to participate in a market under excessive cost pressure. Airlines as well as maintenance, repair and overhaul companies have to cut costs wherever possible. In Brazil, dollar variation, customs taxation and bureaucracy, and market instability make the scenario even more challenging.

Maintenance costs represent 10% to 15% of an airline operating costs. In the last 30 years, the airlines around the world are outsourcing their aircraft and components maintenance. However, in Brazil, the limited number of maintenance centers and the need to export the parts to perform maintenance makes the scenario for Brazilian Airlines different.

The main goal of this research is to demonstrate the positive and negative aspects for a Brazilian Airline to repair its aeronautical components in house, instead of outsourcing outside the country. This study explains the factors that must be taken into consideration, the methodology for analysis in addition to external factors. The final goal is to provide a list of factors that must be evaluated before insourcing or outsourcing a component repair in Brazil.

Chapter III

Methodology

This chapter describes the methodology used to evaluate the technical, operational and the financial aspects for a Brazilian airline to perform its component maintenance repair in house.

The proposal is to minimize the airline total maintenance costs by evaluating the elements involved in the internalization of aircraft components repair and comparing it with outsourcing to a repair station outside Brazil. Any reduction in maintenance cost enhances the competitiveness of an airline (Fritzsche et al., 2014).

Experimental Design

The development of internal capability to perform maintenance on aeronautical components requires a technical and financial evaluation.

The technical evaluation takes into consideration the information available in the original equipment manufacturer (OEM) component maintenance manual (CMM) where it describes the technology involved, tools, equipment, bench tests, subparts and staff training. All this information is part of the capability development for components repair.

The required investment to buy tools, equipment, bench tests and training are raised through quotations. The values provide the necessary information for net present value (NPV) calculation, which is part of the financial evaluation. The net present value (NPV) is the difference between the present value of cash inflows (internal repair) and the present value of cash outflows (external repair) over a period (Tse, 2017).

The viability for an airline to internalize its component repair will depend on the forecast of the volume of components, the amount of investment, complexity of technology involved and external component repair costs.

The formula to calculate NPV is:

$$NPV = \sum_{t=1}^{T} \frac{Ct}{(1+r)^t} - Co$$

Where:

Ct = net cash inflow during the period t

Co = total initial investments costs

r = discount rate

t = number of time periods

A positive net present value indicates that the project earnings generated by the investment exceeds the anticipated costs.

In addition to the NPV, the payback period is another important financial concept used for investment return evaluation. The payback provides an indication of the period (in years) to recover the initial investment (Tse, 2017).

$$Payback\ Period = \frac{Initial\ Investment}{Net\ Annual\ Cash\ Flow}$$

Another important financial tool used to measure the viability of the project is the Internal Rate of Return (IRR). This parameter is used to compare the discount rate of the invested capital with the cost of the capital. If the discounted rate is greater than the cost of capital, the investment is viable (Tse, 2017)

IRR is the discounted rate when NPV is equal zero. So, IRR is calculated through the equation below:

$$0 = \sum_{t=1}^{T} \frac{Ct}{(1 + IRR)^t} - Co$$

Airline Inventory Level

Airline punctuality is a basic requirement for customer satisfaction and brand reputation. Punctuality involves the balance of several complex factors as reliability of the fleet and components, distribution and level of inventory at the operational base, crewmembers training standardizing the type of operation and process effectiveness.

Spare parts inventory exist to serve maintenance planned and unplanned activities. Based on an analysis conducted in 2012 by the International Air Transport Association (IATA) Maintenance Cost Task Force, the maintenance costs can be reduced by good planning. An excess of spare parts inventory leads to an immobilized asset, increasing costs and impedes cash flows, whereas inadequate spare parts can result in costly flight cancellations or delays with a negative impact on airline performance. In Brazil, it is critical to consider the increase on turnaround time for a component outsourcing repair outside the country due to complexity, bureaucracy and timing involved in the customs'. The timing expended in the customs process reduces the availability of serviceable spare parts in the company's inventory.

Most of the maintenance activities performed in an aircraft are planned, however there are potential risks for some components to fail prematurely and this results in additional impacts in operations.

Airbus provided in March 2015 a mathematical model to calculate airlines required inventory level. This model uses a mathematical principal based on Poisson distribution (Bethea, 1995). Poisson distribution calculates the probability of an event to happen in a given time interval and the result is independent of any other time interval.

Airbus used Poisson distribution to calculate the stock level protecting the operation by making spare parts available and minimizing the investment by requesting a minimum resupply.

The operation of an airline has a demand profile for spare parts based on the equation:

$$D_{ann} = \frac{FH\ x\ FS\ x\ QPA}{MTBUR}$$

Where:

D_{ann}: Annual Demand

FH: Flight Hours per aircraft per year

FS: Number of Aircrafts in the Initial Provision Period

QPA: Quantity per aircraft

MTBUR: Mean time between unscheduled removals for certain items

A component resupply time can be calculated by the equation:

$$RST = \left[\left((MST + TT)x\left(1 - \frac{SCR}{1000}\right)\right) + ((LTM + AT)x\left(\frac{SCR}{1000}\right))\right]$$

Where:

RST: Re-Supply Time

MST: Max/Mean shop processing time

TT: Transit Time

SCR: Scrap Rate

LTM: Lead Time

AT: Administration Time

And, the inventory level can be calculated by the equation below:

$$D_{RST} = \frac{Dann}{365}\ x\ RST$$

Where:

D_{RST}: Expected Demand during Re-Supply Time

The final goal for an inventory analysis is to keep stock availability above the removal level, meaning parts are available when required. The Poisson distribution formula uses the probability of a part to failure and recommends a quantity based on stock protection level.

The equation is:

$$P\{R \leq m\} = e^{-D_{RST}} x \sum_{0}^{m} \frac{(D_{RST})^m}{m!}$$

Where:

P: Probability

R: Number of Removal

m: Recommended Quantity

Poisson distribution calculation requires an iterative process assuming a recommended quantity based on stock level protection. Stock level protection is a risk assumed by the company that, in accordance with Airbus recommendation, can varies from 80% to 98% dependent on the operation impact. The criticality of a component in the operation is divided in accordance with the price of the component and the severity of the operation impact.

Data Source(s), Collection, and Analysis

This study considers a sample of aeronautical components divided in hydraulic, electric, electronic, emergency, pressurized vessels and pneumatic technologies. The relevance of these components takes into consideration aircraft operational impact, component costs (new and repair), quantity installed on the aircraft and frequency of repair. The final goal is to reveal the required investment to develop the capability to perform maintenance in house and compare with the costs to outsource repairs outside the country.

The size of the sample was chosen based on the Yamane's Sample Size formula (Yamane, 1967). The Yamane formula permits to calculate an ideal sample size given a desired level of precision, desired confidence level and the estimated proportion of the attribute present in the population.

There are several ways to calculate the sample size for different study designs such as diagnostic test studies, census for small populations, using published tables, and applying formulas to calculate a sample size (Cochran, 1977).

Sample size determination is the technique of choosing the number of observations to include in a sample. The sample size is a relevant part of any research in which the target is to make conclusions about the population from a sample.

Yamane's methodology offers a basic formula to calculate sample sizes. The target of the calculation is to establish an acceptable sample size, which can estimate results for the whole population with a reliable precision. This formula was used to calculate the sample size and is shown below.

The equation is:

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

Where:

n: sample size

e: desired level of precision (i.e. the margin of error)

N: population size

Summary

Maintenance costs are a relevant aspect for airlines operations and any optimization in this process, that results in costs reduction enhances airlines competitiveness.

Components maintenance costs represent around 24% of an airline total maintenance costs (IATA – 2015). In parallel, the availability of spare parts in stock is crucial to keep operations, however an excess of inventory leads to immobilized assets, increasing costs and obstructing cash flow.

Airbus recommends the calculation of stock level based on Poisson distribution where it considers the required protection level. The statistical distribution drives the operators to evaluate the risks of keeping a low or high stock depending on the impact to the operation.

Poisson distribution is highly impacted by the TAT of a component repair where higher TAT requires higher stock level and vice versa. Consequently, airlines in house components repair is an opportunity to reduce components repair TAT, reducing inventory level. However, to perform in house repairs, it is necessary to invest in tools, machines, equipment, manpower and training, as specified by components manufacturers in components maintenance manuals.

The financial viability to perform in house repair versus outsourcing to international companies can be calculated through NPV and Payback (Tse, 2017). The elements involved in this financial, operational and technical evaluation is demonstrated through components sample based on Yamane´s Sample Size Formula.

Chapter IV

Outcomes

The operation of an air carrier is dependent on the strategy to balance all related costs and guarantee a safe and timely operation.

Maintenance costs are divided mainly in line, heavy, components and engine maintenance and they represent around 11% of the total operating costs for an air carrier (Vieira 2016).

This research is based on opportunities to reduce components maintenance costs that constitute around 24% of the total maintenance costs (IATA, 2015).

As the aircraft and its components operation have their natural degradation due to operation use, maintenance schedule is one of the most important to reestablish the level of safety and reliability of the components (Kinnisson, 2012).

Components degradation results in planned and unplanned maintenance. Planned maintenance facilitates the prediction of the inventory level, where and when to perform the activity. Unplanned maintenance requires a quick recovery from maintenance team to reestablish the operation.

Airbus recommends the use of Poisson distribution to define inventory level. This equation considers the risk assumed by the company to cover the operation. Normally, the risk assumed can vary from 80% to 98% dependent on the component operational impact (Airbus, 2015).

The impact of a component to the aircraft operation is divided in three main categories per Airbus definition: go, go if and no go. See below the definition of each category:

- Go: there is no impact to the aircraft operation nor change to operational procedures (Airbus, 2018);
- Go if: there is no impact to the immediate aircraft operation but it requires changes on the operational procedures (Airbus, 2018);

  Note: A combination of several “Go If” conditions could result in a “No Go” condition (Airbus, 2018)

- No Go: there is impact to the aircraft operation and requires immediate action from the maintenance team before next flight (Airbus, 2018).

Inventory analysis

The determination of the inventory level for an air carrier is a complex process and requires deep evaluation and compromise between keep the operation in a safe level and the amount of immobilized capital. In other words, the air carrier needs availability of spare parts to keep and recover the operation as quickly as possible, however high level of inventory represents immobilized capital on assets too.

Aircraft components have high aggregated value due to their technology, certification and small number of manufacturers. As a consequence, air carriers spend lots of energy to identify viable options to optimize inventory level. Reductions in the inventory levels and the amount of immobilized capital are strategic for an air carrier operation.

Companies adopt strategies to maximize the return of capital applied. The goal is to obtain maximum return with minimum investment. From the operational perspective, this is equivalent to maximizing profit while minimizing assets. Therefore, an idea of demobilizing the assets gains strength within companies (Lima, 2003).

In the commercial aviation industry, the total values of spare parts inventories is around $ 45 million dollars, with an annual cost of opportunity estimated at $ 8 billion dollars (Sandvig and Allaire, 1998). This value is higher than the total profit obtained by the sector (Sandvig and Allaire, 1998).

According to Oscar (2010), the aircraft components are repairable parts with high aggregated value, low annual removal rate and low availability in the marketing, being difficult to be purchased. In Brazil, the procurement process is even more difficult, considering that aircraft parts are mostly imported, having few suppliers and a bureaucratic and complex customs' process. Furthermore, the distance increases the storage and transportation costs.

This research considers a fictitious air carrier called ABC Airlines that operates in Brazil with a fleet of sixty aircrafts manufactured by Airbus model A320. The sixty aircrafts was chosen based on configuration and similarities involving the manufactures components by aircraft Air Transport Association (ATA-100) chapters. These similarities shall be considered in order to classify the sample size as valid for the research. The inventory level is calculated through Poisson Distribution and considers a centralized warehouse that is responsible for the distribution of spare parts to the other operational bases.

The main goal of the mathematical model of this research is to estimate the reduction of the inventory level considering the turnaround time of components repair in house versus turnaround time of outsourcing the component repair to a company outside the country. Furthermore, the calculation takes into consideration the repair costs to perform maintenance in house versus perform maintenance outsourcing.

Christopher (2009) and Ballou (2006) explored the concept of supply chain just in time where the size of the inventory tends to zero. However, the customs bureaucracy, high costs of components and the limited number of repair stations, requires a deep evaluation and investment in a safe inventory level to reduce operation impact.

Sample Size Determination

The main goal of this research is to describe the elements that must be considered to perform the technical, operational and financial evaluation for a component repair in house versus outsourcing to a repair station outside the country.

ABC Airline received a mission from the top executives to reduce components repair costs. The company has contracts with several repair stations for outsourcing repair of hundreds of components. The total list of components contained in these contracts were sent to ABC Engineering team and they made a previous evaluation to separate components by low, medium and high investments in tools and equipment for repair internalization.

This research is considering a total population of 186 different components that were classified by engineering team as low investment. Medium and high investments were not considered in this research.

The focus is to reduce repair costs and inventory level. All the 186 components are classified as “no go” or “go if”, resulting in operational impact to the company. ABC Airline is evaluating how to reduce costs, so the research will analyze the costs for in house repair versus the actual outsourcing repair costs.

The goal is to validate the evaluation method, so this research uses Yamane´s Sample Size Formula to reduce the sample and provides significance to the study.

See below the calculations to define the size of the sample:

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

Where:

N = 186

e = 0.1

So,

$$n = \frac{186}{1 + 186 * (0.1)^2} \quad => \quad n = 65\ samples$$

In accordance with Yamane´s Sample Size Formula, the analysis of 65 components to validate the model is needed.

Calculation of Inventory Level

The calculation of inventory level through Poisson Distribution takes into consideration the size of the fleet, annual removal rate, quantity of installed components, reliability and the desired level of operation protection. As recommended by Airbus, the inventory protection level is 95% for the “go if” components and 98% for the “no go” components.

The annual component removal rate and components reliability are based on historical information from ABC Airlines. The baseline is mainly focused on the information from the year of 2017.

In the figure 4.2., Airbus uses the Poisson model to determine how to select and choose the level of protection, as well as the quantity of the components recommended through an estimated demand.

ESTIMATED DEMAND [D_{rst}]

m	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
0	.368	.333	.301	.273	.247	.223	.202	.183	.165	.150	.135
1	.736	.699	.663	.627	.592	.558	.525	.493	.463	.434	.406
2	.920	.900	.879	.857	.833	.809	.783	.757	.731	.704	.677
3	.981	.974	.966	.957	.946	.934	.921	.907	.891	.875	.857
4	.996	.996	.992	.989	.986	.981	.976	.970	.964	.956	.947
5	.999	.999	.998	.998	.997	.996	.994	.992	.990	.987	.983
6	1.000	1.000	1.000	1.000	.999	.999	.999	.998	.997	.997	.995
7					1.000	1.000	1.000	1.000	.999	.999	.999
8									1.000	1.000	1.000

RECOMMENDED QUANTITY [*m*]

PROTECTION LEVEL [*PL*]

Figure 4.1. Poisson Sample Table. “Mathematical Model” 2015, Airbus Services Solutions.

This research used the Microsoft Excel to develop the Poisson Distribution Matrix in order to determine the amount of recommended inventory for all 65 components from the sample.

The technical and financial evaluation considered a period of 5 years where the components MTBUR is reduced 10% per year due fleet aging. Furthermore, the research is based on a stable fleet of 60 aircrafts and a component resale price at 60% of the full price of a new component. Price of the components are based on ABC Airlines.

Poisson Distribution calculations require the use of the four formulas below where transit time and lead-time have big influence on the inventory level.

$$D_{ann} = \frac{FH\ x\ FS\ x\ QPA}{MTBUR}$$

$$RST = \left[\left((MST + TT)x\left(1 - \frac{SCR}{1000}\right)\right) + ((LTM + AT)x\left(\frac{SCR}{1000}\right))\right]$$

$$D_{RST} = \frac{Dann}{365}\ x\ RST$$

$$P\{R \leq m\} = e^{-D_{RST}} x \sum_{0}^{m} \frac{(D_{RST})^m}{m!}$$

All calculations of Poisson Distribution are based on ABC Airlines historical components repair turn-around time that is 15 days' repair plus 3 days logistics for the entire country. Therefore, the in house repair turn-around time considered is 18 days. The outsourcing repair outside the country turn-around time was based on Airbus recommendation for external repairs that is 60 days. These 60 days considers the exportation, repair and importation process. This number can be highly increased according to ABC Airline from 60 to up to 120 days in case of Brazilian customs strike, as observed in 2018

According to Airbus (2015), for parts where lead-time material is not available, the defaults to present values depending on the type of material should be considered as mentioned in the figure 4.2

Type of material	LTM [days]
Airbus Proprietary Parts	10
Supplier Equipment	60
Supplier Equipment Breakdown Parts	60
Standard Hardware	30

Figure 4.2. LTM default Table. "Mathematical Model" 2015, Airbus Services Solutions.

Net Present Value and Payback

The internalization of components repair for an airline depends on the technical expertise of the engineering team to develop the in house capability and the correct determination of the investment amount in tools, equipment, bench tests and trainings.

The calculation of the net present value and payback considers all the investments and costs for an in house repair and compare them with the costs of outsourcing the component repair outside the country. See below the equations used for viability calculation:

$$NPV = \sum_{t=1}^{T} \frac{Ct}{(1+r)^t} - Co$$

$$Payback\ Period = \frac{Initial\ Investment}{Net\ Annual\ Cash\ Flow}$$

The investments in tools, equipment, bench tests and trainings to develop capability for the 65 components (sample generated by Yamane´s Sample Size Formula) were raised based on quotations available at ABC Airline.

The total amount of investment in tools, equipment, bench tests and trainings is U$D 4,212,000.00 where this value must be invested in the first year to guarantee the development of capability to perform the component repair.

The initial investment in consumable materials for components repair is U$D 1,289,331.00. These materials are subparts as o-rings, packing, bolts, chemical materials and several others, used to perform the repair on the components.

The investment in consumable material is considered only in the year zero because it represents an increase in company's inventory. From years 1 to 5, the expenses on subparts are already considered as the difference of the costs for in house components repair versus outsourcing to a repair station outside Brazil.

Historical data from ABC Airlines show that in house repair is 35% cheaper when comparing to outsourcing. The main reason for this substantial difference between the in house versus outsourcing repair costs is the cheapest man-power costs in Brazil when compared to US and Europe. Furthermore, the in house repair does not consider the profit margin of the repair station because it is an internal gain.

The reduction on turn-around time considering the in house repair (TAT 18 days) versus outsourcing repair (TAT 60 days) allows a reduction in inventory of approximately U$D 7,088,263.00 and a reduction in shipping handling expenses of U$D 129,000.00. The total inventory reduction value was calculated considering the quantity of components available for sale after inventory level adjustment at 60% of the price of a new component. ABC Airline historical shows that 60% is a market price for used components to be sold as serviceable. Therefore, turnaround time is an important factor to calculate inventory level through Poisson Distribution.

The table 4.1 represents the five years cash flow projections where investments are performed mainly in the first year and sales of overstock, and due repair turnaround time reduction is divided in two years. Selling the overstock in two years will guarantee the operation and will accommodate the in house repair learning curve.

Payback of the investment happens on the first year with an internal return rate of 54%.

Table 4.1

Five years projection cash flow

	ECONOMIC VIABILITY (x 1000)					
YEAR	0	1	2	3	4	5
CASH FLOW	$ -5.501,00	$ 4.596,00	$ 4.596,00	$ 1.052,00	$ 1.052,00	$ 1.052,00
	PAY IN					
IN-HOUSE GAIN		$ 923,00	$ 923,00	$ 923,00	$ 923,00	$ 923,00
SALE OF ASSETS		$ 3.544,00	$ 3.544,00	$0,00	$0,00	$0,00
HANDLING		$ 129,00	$ 129,00	$ 129,00	$ 129,00	$ 129,00
	PAYOUTS					
MATERIAL (INITIAL INVESTMENT)	$ 1.289,00	$ -	$ -	$ -	$ -	$ -
TOOLS	$ 4.212,00	$ -	$ -	$ -	$ -	$ -
DISCONTED CASH FLOW		$ - 4.178,00	$ - 3.798,00	$ - 790,00	$ - 718,00	$ - 653,00
PAYBACK		$ 2.889,00	$ 6.687,00	$ 7.478,00	$ 8.196,00	$ 8.850,00
COST OF CAPTAL (%)	0,1					
NPV		$ 4.638,00				
IRR		54%				
IP		1,84				

Note: Calculations are available on appendix.

Summary

Maintenance costs represents around 11% of the total air carrier operating costs (Vieira, 2016) and only components maintenance costs represent around 24% of the total maintenance costs (IATA, 2015).

Components operation have its natural degradation and maintenance is applied to reestablish the level of safety and reliability (Kinnisson, 2012). Maintenance is divided into planned where the activity is predicted, scheduled and prepared for the execution, and unplanned where the operation is reestablished by a quick recovery from maintenance team. Both, planned and unplanned maintenance requires a good inventory prediction.

The level of inventory is calculated based on Poisson Distribution taken into consideration the probability of a component to failure. High inventory level represents capital immobilized on assets and low inventory level represents risk to the operation.

Poisson Distribution considers the turnaround time for a component removed from service as unserviceable, be repaired and returned as serviceable. Higher turnaround time requires higher inventory level.

Brazil has a limited number of components repair stations, therefore several components repair must be outsourced to companies outside Brazil. Brazilian Customs is complex and bureaucratic adding costs and time to the repair turnaround time.

The internalization of components repair requires a deep technical evaluation to develop capabilities as tools, equipment, bench tests and skilled personnel. The investments in these developments, internal repair costs plus the reduction in inventory due to reduction in turnaround time can be compared to the external repair costs through net present value calculation.

This research considered a population of 186 components that have operational impact on ABC Airline and they are actually being repaired in a repair station outside Brazil. A sample of 65 components was randomly chosen based on Yamane´s Sample Size Formula.

Net present value and payback were calculated considering a 5-year period in a fleet of 60 aircrafts model Airbus A-320FAM where components reliability decreased 10% per year due fleet aging. Based on ABC Airlines historical, the resales price of an inventory component is 60% of the total price of a new component. Furthermore, the in house repair cost is 35% cheaper when comparing to outsourcing outside Brazil.

The turnaround time for in house component repair is around 18 days. The turnaround time for an outsourcing component repair outside Brazil is around 60 days. This turnaround time reduction allows an inventory reduction of U$D 7,088,263.00 and a reduction in shipping handling expenses of U$D 129,000.00.

The investment in tools, equipment, bench tests and trainings is around U$D 4,212,000.00 and must be invested in the first year to guarantee the repair capability in the first year. Additionally, an investment of U$D 1,289,331.00 in consumable materials (O-rings, packing, sealants, bolts) to guarantee components repair is needed.

Net present value and payback calculations show an internal return rate of 54% and a payback of less than one year.

Chapter V

Project Conclusions

The total maintenance costs represent around 11% of the total air carrier operational costs. Maintenance is mainly divided in line, heavy, components and engine maintenance. Components maintenance cost represents 24% of the total maintenance costs.

The operation of an airline is dependent on availability of spare parts to support aircraft schedule and unscheduled maintenance. The determination of inventory levels must balance the availability of spare parts to keep the operation and the amount of capital immobilized on inventory. Aeronautical components have high aggregated value.

Airbus recommends the use of Poisson Distribution to calculate the level of inventory to protect the airline operation due the probability for an aircraft component to fail. Poisson Distribution takes into consideration the turnaround time for a failed component to be repaired and returned to the company inventory. Longer turnaround time requires higher inventory to guarantee spare parts availability.

Aeronautical components must be repaired on homologated repair stations. In Brazil, there are few repair stations with limited scope. Therefore, Brazilian Airlines are obligated to outsource several components maintenance to repair stations outside the country.

Outsourcing components maintenance to a repair station outside the country requires exportation and importation of the component through Brazilian Customs. This process is bureaucratic and requires several days to be cleared. Historical data shows an average of 60 days turnaround time for an outsourced component repair outside the country.

The fictitious ABC Airline already has the capability to perform repairs in several components models. The main goal of this research was to evaluate the technical and financial elements involved in the expansion of the actual capability to repair components in house. Historical data showed that in house repair turnaround time is around 15 days.

The expansion of component repairs capability involves a deep evaluation of the technical aspects that involves tools, equipment, bench tests and trainings. The amount of investment required to buy tools, equipment, bench tests and training were raised through market quotations that are already available at ABC Airline.

The financial evaluation considered the amount of capital invested in tools, equipment, bench tests and trainings, the projected in house repair costs, the volume of repairs per year and the possibility of inventory reduction due turnaround time reduction versus the outsource repair costs.

This research provided elements on how to calculate the reduction in inventory levels, keeping the operation protected. Furthermore, it showed the mathematical model used to measure the financial viability to perform aeronautical components in house repair for a Brazilian airline.

Recommendations

The development of components repair capability is based on the Original Equipment Manufacturer (OEM) Component Maintenance Manual (CMM). This manual brings all the technical information required, as tools, equipment, bench tests, consumable materials and others.

There is a significant commercial interest from the OEM to keep control of the technology and sell the repair services by themselves. In several cases, the price of the tools, equipment and bench tests to develop in house capability result in an unviable financial analysis.

The investment related to capability development can be considerably reduced when the repair station has a good and specialized development engineering team. This team is responsible to technically evaluate the required tools, equipment and bench tests, and develop these devices internally.

The internalization of components repair requires a good consumable materials planning. Every aeronautical component is composed of several subparts that must be available in stock for replacement. Subparts prices are low when compared to the price of the component. However, the lack of some subparts will not allow the full assembly of the component, stopping the final release of the aeronautical part.

The technology involved in components repair and their intrinsic complexity requires constant and recurring technicians training. The learning curve for a mechanic takes around two years to get the basic experience. The mechanics expertise keeps increasing along the years. Therefore, the company must be very cautious with employees' turnover and must create means to keep the engagement.

Airlines' On Time Performance in Brazil is monitored by the aeronautical authority and it has a strong relation with reputation. Aircrafts reliability has a close relation to components reliability.

The internalization of components repair is an important factor to monitor and increase components reliability. The engineering team can evaluate components degradation and failure modes, and propose product and process improvements.

For future researches, we could consider the same methodology of using Poisson for spare parts in order to reduce the number of parts in the inventory.

Another point to be considered as a potential to the aviation industry is to strengthen the development of airline maintenance internal capability through customized benches, tools and reverse engineering.

With the aim of maximizing the benefits of this research as well as to strengthen insourcing maintenance in Brazil, the approval of repairs beyond those authorized and stated in the manufacturers' manuals should be considered. The manufacturers in order to protect themselves, they restrict some levels of repairs, forcing the airlines sending their components to them. This approval might reduce the level of airlines inventories.

For further researches, the airlines can conduct a benchmarking with other companies, considering the same peculiarities and operational complexity as Brazil, mainly regarding to customs process and the impact of exchange variation, as well as to evaluate the feasibility to provide repair services.

The financial evaluation was performed considering the actual Brazilian political and economic scenario. A sensitivity analysis was not performed considering projections, and this analysis can be part of further researches considering the influence of rate exchange variation, repair turn-around time impact and component reliability. Future researches can evaluate how much these parameters have impact on in house repair financial viability.

At the end, this research did not consider cost opportunity for payback calculation, consequently it represents an opportunity to be better explored in further researches. The availability of components in the company warehouse, when necessary to keep the aircraft operation, has an important influence on financial evaluation. The financial analysis of this research considered only the inventory reduction impact, however the internalization has a financial gain that is bigger when considering the operation impact due flights cancelations and flights delay. This research doesn´t cover this parameters generating an opportunity for further studies in this subject.

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Appendix A

Tables

POISSON					
Part Number	Value		Component Sales		
Component FH	4156		**Component Price**	15,453.00	(new)
Items per Acft	2		**Tax Rate**	10%	aa
Fleet	60			0.80%	am
Removal per Year	14				
MTBUR	53434		**Removal factor**	10%	(per year)
PL (%)	95		**Items to Sell**	9	
Fleet FH	4660		**Sales factor**	45%	(new one)

Warehouse Analysis (TAT - 15 days)					
Year	1	2	3	4	5
N° of Acft	60	60	60	60	60
MTBUR	48090	43281	38952	35056	31550
Demand	0.716	0.796	0.884	0.983	1.092
	0.7	0.8	0.9	1	1.1
Stock	**2**	**2**	**2**	**3**	**3**

Warehouse Analysis (TAT - 60 days)					
Demand	2.867	3.185	3.539	3.933	4.370
	2.9	3.2	3.5	3.9	4.4
Stock	**6**	**6**	**7**	**7**	**8**
Difference	4	4	4	4	5
To buy	4	0	0	0	1
To Sell	9	0	0	0	1
Spent (TAT 60 day)	$ 61812.00	0	0	0	$ 15453.00

	ECONOMIC VIABILITY				
QUARTERLY	0	1	2	3	4
CASH FLOW	$ -1.289.331,00	$ 1.964.525,38	$ 1.964.525,38	$ 4.070.525,38	$ 4.070.525,38
	PAY IN				
IN-HOUSE GAIN		$ 923.127,38	$ 923.127,38	$ 923.127,38	$ 923.127,38
SALE OF ASSETS		$ 3.115.148,00	$ 3.115.148,00	$ 3.115.148,00	$ 3.115.148,00
HANDLING		$ 32.250,00	$ 32.250,00	$ 32.250,00	$ 32.250,00
	PAYOUTS				
MATERIAL	$ 1.289.331,00	$ -	$ -	$ -	$ -
TOOLS		$ 2.106.000,00	$ 2.106.000,00	$ -	$ -
DISCONTED CASH FLOW		$ -1.785.932,16	$ -1.623.574,69	$ -3.058.245,97	$ -2.780.223,60
PAYBACK		$ 496.601,16	$ 2.120.175,86	$ 5.178.421,82	$ 7.958.645,43
COST OF CAPTAL (%)	0,1				
NPV		$ 7.958.645,43			
IRR		169%			
IP		7,17			

	ECONOMIC VIABILITY					
YEAR	0	1	2	3	4	5
CASH FLOW	$ -5.501.331,00	$ 4.596.258,88	$ 4.596.258,88	$ 1.052.127,38	$ 1.052.127,38	$ 1.052.127,38
	PAY IN					
IN-HOUSE GAIN		$ 923.127,38	$ 923.127,38	$ 923.127,38	$ 923.127,38	$ 923.127,38
SALE OF ASSETS		$ 3.544.131,50	$ 3.544.131,50	$0,00	$0,00	$0,00
HANDLING		$ 129.000,00	$ 129.000,00	$ 129.000,00	$ 129.000,00	$ 129.000,00
	PAYOUTS					
MATERIAL (INITIAL INVESTMENT)	$ 1.289.331,00	$ -	$ -	$ -	$ -	$ -
TOOLS	$ 4.212.000,00	$ -	$ -	$ -	$ -	$ -
DISCONTED CASH FLOW		$ -4.178.417,16	$ -3.798.561,06	$ -790.478,87	$ -718.617,16	$ -653.288,32
PAYBACK		$ 2.889.086,16	$ 6.687.647,22	$ 7.478.126,09	$ 8.196.743,25	$ 8.850.031,58
COST OF CAPTAL (%)	0,1					
NPV		$ 4.638.031,58				
IRR		54%				
IP		1,84				

	ECONOMIC VIABILITY (x 1000)					
YEAR	0	1	2	3	4	5
CASH FLOW	$ -5.501,00	$ 4.596,00	$ 4.596,00	$ 1.052,00	$ 1.052,00	$ 1.052,00
	PAY IN					
IN-HOUSE GAIN		$ 923,00	$ 923,00	$ 923,00	$ 923,00	$ 923,00
SALE OF ASSETS		$ 3.544,00	$ 3.544,00	$0,00	$0,00	$0,00
HANDLING		$ 129,00	$ 129,00	$ 129,00	$ 129,00	$ 129,00
	PAYOUTS					
MATERIAL (INITIAL INVESTMENT)	$ 1.289,00	$ -	$ -	$ -	$ -	$ -
TOOLS	$ 4.212,00	$ -	$ -	$ -	$ -	$ -
DISCONTED CASH FLOW		$ -4.178,00	$ -3.798,00	$ -790,00	$ -718,00	$ -653,00
PAYBACK		$ 2.889,00	$ 6.687,00	$ 7.478,00	$ 8.196,00	$ 8.850,00
COST OF CAPTAL (%)	0,1					
NPV		$ 4.638,00				
IRR		54%				
IP		1,84				

PN	C16291AA		
FH	4156	Valor Componente em US$	15453
No. por ACFT (n)	3	Tax Rate	='Dados Gerais'!B2 aa
No. de ACFT (N)	60		=(POTÊNCIA(1+N4;30/360)-1) am
No. Remoções (NR)	14		
MTBUR	=INT((C3*C4*C5)/C6)	% Recuperação c/ a Venda	0.45
Demand (E)	=($C$17*$C$4*C5)*(1/$C$8)*(	No.Componente(s) a ser vendido(s)	0
Demand ARRED (E)	=ARRED(C9;1)		
Rodízio Atual	=SE(C10>10;ARRED(PROCV	% Aumento Remoções Ano	0.1
Rodízio Atual Real	11		
PL (%)	95		
FH	4660		

	1	2	3	4	5
No. de ACFT (N)	60 60 =(D19+E19)/2	60 60 =(G19+H19)/2	60 60 =(J19+K19)/2	60 60 =(M19+N19)/2	60 60 =(P19+Q19)/2
MTBUR	=INT(C8-C8*$N$10)	=INT(F20-F20*$N$10)	=INT(I20-I20*$N$10)	=INT(L20-L20*$N$10)	=INT(O20-O20*$N$10)
Demand (E)	=($C$17*$C$4*F19)*(1/F20)*($C$23/3	=($C$17*$C$4*I19)*(1/I20)*($C$2	=($C$17*$C$4*L19)*(1/L20)*(C	=($C$17*$C$4*O19)*(1/O20)*($C	=($C$17*$C$4*R19)*(1/R20)*($C
	=ARRED(F21;1)	=ARRED(I21;1)	=ARRED(L21;1)	=ARRED(O21;1)	=ARRED(R21;1)
TAT 15	=SE(F22>10;ARRED(PROCV($C$15;	=SE(I22>10;ARRED(PROCV($C	=SE(L22>10;ARRED(PROCV($C	=SE(O22>10;ARRED(PROCV($	=SE(R22>10;ARRED(PROCV($
Demand (E)	=($C$17*$C$4*F19)*(1/F20)*($C$27/3	=($C$17*$C$4*I19)*(1/I20)*($C$2	=($C$17*$C$4*L19)*(1/L20)*(C	=($C$17*$C$4*O19)*(1/O20)*($C	=($C$17*$C$4*R19)*(1/R20)*($C
	=ARRED(F25;1)	=ARRED(I25;1)	=ARRED(L25;1)	=ARRED(O25;1)	=ARRED(R25;1)
TAT 60	=SE(F26>10;ARRED(PROCV($C$15;	=SE(I26>10;ARRED(PROCV($C	=SE(L26>10;ARRED(PROCV($C	=SE(O26>10;ARRED(PROCV($	=SE(R26>10;ARRED(PROCV($
Diferença	=F27-F23	=I27-I23	=L27-L23	=O27-O23	=R27-R23
Necessidade	=F28-E28	=I28-F28	=L28-I28	=O28-L28	=R28-O28
Surplus	=SE(F29<0;C30+(F29*-1);SE(C29>0;(	=SE(I29<0;F30+(I29*-1);SE(F29	=SE(L29<0;I30+(L29*-1);SE(I29>	=SE(O29<0;L30+(O29*-1);SE(L2	=SE(R29<0;O30+(R29*-1);SE(O
Necessidade s/ Rodízio Atual	=SE(E(F29>0;F30>0);F29-F30;SE(F2	=SE(E(I29>0;I30>0);I29-I30;SE(I	=SE(E(L29>0;L30>0);L29-L30;SE	=SE(E(O29>0;O30>0);O29-O30;	=SE(E(R29>0;R30>0);R29-R30;
Comprar (Não Capacitando)	=(F32)	=I32	=L32	=O32	=R32
Pode Vender (Capacitando)	=SE(C13-F23>0;C13-F23;0)				
Gasto (Não Capacitando)	=SE(F33>0;F33*$N$3;0)	=SE(I33>0;I33*$N$3;0)	=SE(L33>0;L33*$N$3;0)	=SE(O33>0;O33*$N$3;0)	=SE(R33>0;R33*$N$3;0)
Gasto (Não Capacitando)					
=VPL(N4;I36:R36)+F36					
Ganho (Capacitando)					
=N3*N8*N7					
Total					
=B38+B40					

	ECONOMIC VIABILITY					
YEAR	0	1	2	3	4	5
CASH FLOW	=(SOMA(I7:I10)-(SOMA(I12:I14)))	=(SOMA(J7:J10)-(SOMA(J12:J14)))	=(SOMA(K7:K10)-(SOMA(K12:K1	=(SOMA(L7:L10)-(SOMA(L12:L1	=(SOMA(M7:M10)-(SOMA(M12:	=(SOMA(N7:N10)-(SOMA(N12:N
	PAY IN					
IN-HOUSE GAIN		923127,38	923127,38	923127,38	923127,38	923127,38
SALE OF ASSETS		3544131,5	3544131,5	0	0	0
HANDLING		129000	129000	129000	129000	129000
	PAYOUTS					
MATERIAL (INITIAL INVESTMENT)	1289331	0	0	0	0	0
TOOLS	4212000	0	0	0	0	0
DISCONTED CASH FLOW		=VP($B$17;J$4;J$5)	=VP($B$17;K$4;;K$5)	=VP($B$17;L$4;;L$5)	=VP($B$17;M$4;;M$5)	=VP($B$17;N$4;;N$5)
PAYBACK		=(-J$15+$B$5)	=(-K$15+J16)	=(-L$15+K16)	=(-M$15+L16)	=(-N$15+M16)
COST OF CAPTAL (%)	0,1					
NPV		=VPL(I17;J5;K5;L5;M5;N5)+I5				
IRR		=TIR(I5:N5)				
IP		=(SOMA(J15:N15))/I5				