Regional Airline's Operational Performance Study and Appropriate Enhancement Techniques

PGA – Portugália Airlines as a case study

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OCTOBER 2009

Abstract

Today's airline industry is a particularly fragile business. Crude prices, world crisis, economy recession, new globalization challenges, green-thinking markets, marginal profits… These are some of the ingredients of what is, for many airline operators, a fatal recipe. The only solution for survival is optimization. A transverse and well-thought optimization.

That is why PGA – Portugália Airlines, a Portuguese Regional Airline, aiming to continuously reach higher efficiency values, initiated a series of studies, based on scholar-industry cooperation model.

The idea for this work began with this initiative of PGA. Initially single oriented to fuel conservation strategies, it developed itself to a broader study. Different optimization tools and solutions are described and an operational performance study is performed covering the various aspects of flight operation, by defining a series of metrics, useful to more accurately understand the company's nature. With the same original data, the company's operational characteristics are then studied in a more statistical perspective. This work also contemplates a savings analysis, taking into account different scenarios more related with flying itself, hence a more practical approach to optimization procedures.

Keywords: Fuel Consumption; Fuel Conservation; Operational Performance; Performance Optimization; Regional Airline.

Introduction

The world is in a continuous changing process. We now live in the so-called global village, boundaries and frontiers are now free from a geographic definition and there's a global accountability for Human action. This globalization has come upon us almost undetected but in a very decisive and definitive manner. It's partly because of it that makes so much sense talking about a global crisis. Global economy is in recession, the increasing demand of resources by emerging countries is unbalancing the trade balance and companies around the world are struggling to remain afloat with only marginal profits.

The aviation industry is particularly sensitive to this economic scenario, since there's a considerable worldwide drop in the demand for tickets. This induces an excessive offer of airlines, hence a stronger competition among them, being the natural response lowering fares and reducing costs, resulting in a marginal operation and in some cases poor passenger satisfaction.

With all these concerns in mind, PGA – Portugália Airlines, a Portuguese Regional Airline is, like many of its pairs, aiming to optimize its operation. That's why PGA started to plan a series of studies which were to focus on performance analysis, optimization tools and procedures and operational costs reduction. These studies were to be conducted based on an academic model, enhancing scholar-industry cooperation and developing human resources, while helping the company to achieve higher standards of efficiency.

The present work is the result of one of these studies. Initially single oriented to fuel conservation strategies, it developed itself to a broader study, reaching from recent green policies to efficiency enhancing maintenance operations, while still making a deep performance analysis with numerous efficiency indicators on both PGA's fleets. This broader range of studies explains this work's title: "Regional Airline's Operational Performance Study and Appropriate Enhancement Techniques".

Motivations

Economic Scenario

Today's airline industry worldwide faces one of the most difficult economic backgrounds since the beginning of commercial aviation. In addition to the serious economical crisis the world has fallen to, the latter years also witnessed ferocious competition among airlines leading to ever minor profit margins, making it more and more difficult for newcomers to succeed and old-timers to remain afloat. Economic protection is often assured to some companies since their bankruptcy would have a serious and unaccountable impact in the economy as literally thousands would become unemployed. However, and counteracting this type of political efforts to minimize the impact of the world crisis on the economy, more specifically in the airline business, the phenomenon of *credit*

crunch[1], recurrent in such economic conditions, arises thus hindering potential investments in fleet renewals or in other strategic sectors of the company reducing its competitive strength.

Aviation, Environment and Health

Aviation facilitates economic and cultural exchanges and is a significant source of employment and growth in many regions. However, aviation also contributes to global climate change, and its contribution is increasing. Even though there has been significant improvement in aircraft technology and operational efficiency this has not been enough to neutralise the effect of increased traffic, and the growth in emissions is likely to continue in the decades to come. In addition, the fact that modern jets operate at high cruise altitudes worsens the effects of engine emissions on higher levels of the atmosphere.

Air pollution can cause a range of health effects including breathing difficulties, heart disease and cancer. Historically, the main air pollution problem was typically been high levels of smoke and sulphur dioxide arising from the combustion of fossil fuels such as coal and oil. The major threat to clean air is now posed by traffic emissions. Motor vehicles emit a wide variety of pollutants which have an increasing impact on urban air quality. Aircraft and airport-related traffic and activities produce the same types of pollutants as road traffic, domestic and industrial sources. Near to airports, airport activities may form a major or even the dominant source of pollution.

Human activities such as the burning of fossil fuels and the destruction of forests are increasing the levels of carbon dioxide, water vapour and other heat-trapping gases in the atmosphere. The addition of these greenhouse gases is enhancing the natural greenhouse effect, making the Earth warmer and changing the climate. The solution lays in reducing global emissions of the greenhouse gases, in particular carbon dioxide. In what the aviation industry is concerned, the main strategies to achieve this goal lay on four pillars:

- ✈ Technology
- ✈ Infrastructure
- ✈ Aircraft Operations
- ✈ Economic instruments

Fuel Conservation Strategies

The general trend in aircraft engine technology development over the past few decades has been to reduce TSFC[2]. Besides reducing fuel consumption, this trend has resulted in lower emissions of pollutants. Developments in

communication, navigation, and surveillance technology, as well as air traffic management systems have enabled more efficient use of the air traffic system. This also brought in some considerable fuel savings. Operational improvements consist of establishing more efficient SOPs like engine out taxiing, better APU management, CI optimization, exploiting the FMS flight efficiency tools, CG fine tuning, and several E&M potential savings like, BOW reduction, engine compressor water wash and good airframe surface trimming and washing. Several economic instruments may be considered as fuel conservations strategies, however none is thought be as effective as the ETS. The Emissions Trading System is an economic tool created with the purpose of reducing the emission of greenhouse gases to the atmosphere, with special emphasises in carbon emissions. The main principle behind ETS is considering carbon as a good itself, with a market-driven cost and a customized trading system based on a *cap* and *trade* concept. If a company comes in below its cap, it has extra credits which it may *trade* with other companies. Companies which exceed their *caps* are penalized for their excess pollution.

Fuel Consumption Optimization

Why is it needed?

Facing such an appalling economic context most of the world's airliners are struggling to keep financial viability and the only survivors will be the ones that manage to achieve the best economical performance optimization possible. In the particular case of a small airline operating a medium size fleet of Regional Jet (RJ) aircraft on short and medium-haul routes, like PGA - Portugália Airlines, some aggravating factors (mainly due to operational conditions), have to be considered. Aircraft operations characteristics like airports served, stage lengths flown and flight altitudes, have a particularly significant impact on the *energy efficiency*[3] of RJs. They fly shorter stage lengths than large aircraft spending more time at airports, taxiing, idling, maneuvering to and from gates, in more technical words, RJ spend a greater fraction of their block hours (BH) in non-optimum, non-cruise stages of flight. It's possible to quantify this ground inefficiency with the difference between block hours (BH) and flight hours (FH), the bigger the difference the higher the inefficiency. This fact is due mostly to the fact that RJ flights' have been focusing on major urban airports sharing their facilities with major airliners, increasing airport congestion. Anyway, RJ require a similar runway length to large aircraft, setting aside some of the available secondary urban airports on which TP have no problem landing or taking-off. Another RJ weakness is their high airborne inefficiency. RJ by definition fly shorter routes than larger aircraft, nonetheless they fly with the same type of engines

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[1] Credit Crunch – A reduction in the general availability of loans or a sudden tightening of the conditions required to obtain a loan from the banks.

[2] TSFC – Engineering measure of an engine's efficiency; it represents the mass of fuel needed to provide the specific net thrust for a given period of time, given in Kg/N.s.

[3] Energy Efficiency – The efficiency of an aircraft measured by units of energy per ASK.

and with similar systems technologies, having very similar altitude related performance charts they all fly preferably at the same altitudes. Other important downside of RJ is their high ratio of cycles per flight hour, meaning that both the aircraft and the engines, complete much more cycles with less flight time. In spite of its disadvantages, RJs are still competitive as their load factors are generally 10 to 30% higher than their direct rivals the TPs. One very plausible reason for this is the passenger satisfaction upon flying on RJ.

In sum, due to a crushing economic scenario, to a more and more global conscience and broader perspective in what climate change is concerned, to operational difficulties and aggressive competition and in first hand, to the need to reduce direct operating costs, fuel consumption optimization is mandatory.

Optimization Tools and Solutions

It is important to keep in mind that optimization solutions are not miraculous actions that will unveil amazing new performance figures, but a series of well-thought ideas considering the very own nature of the company and in which way they are viable to achieve their goals as small parts of a global plan for the company.

The most significant fuel consumption optimization solutions related to maintenance practices are stated below:
- ✈ Controlling the Drag – Prevention of aerodynamic degradation should be a part of maintenance procedures
- ✈ Controlling the Weight – An effective control of an aircraft's weight is of the essence to avoid a
- ✈ Controlling Engine Efficiency – A trend monitoring system is a key feature in keeping the engines running efficiently

Examples of Fuel Consumption Optimization solutions concerning operational characteristics are listed below:

- ✈ Pilot Techniques
  - APU
  - Engine Start-Up
  - Engine out taxi
  - Proper trimming
  - Ice Protection
  - Autolanding
  - Flap setting
- ✈ Controlling Aircraft Weight – A fine-tuned flight planning system is of the essence to know precisely the amount of fuel needed for any given flight
- ✈ Taxi Fuel – Excessive taxi fuel loaded, concurs in extra weight

FMS – Navigator and Engineer

A FMS is a tool designed primarily to compute a flight plan that not only satisfies all the operational constraints that might be imposed on it, while being able to generate the least costly flight possible, but is also a means to enhance cockpit automation, reducing pilot workload. The FMS allows the pilot to program an entire flight plan from start to finish, having the aid of runway details and all the NAVAIDs along the designated route while still being capable of calculating optimal speeds and altitudes for each stage of flight, predicting fuel consumption, ETA and ETE based on integrated performance models of the binomial aircraft/engines.

Cost Index – An unexploited wonder

Along side the FMS there is usually a very important fuel consumption optimization tool, called the Cost Index or the CI. The CI is no more than the ratio between time-related non-fuel costs and the cost of fuel (assuming the fuel has a fixed value for a given sector and period):

$$CI = \frac{C_T}{C_F}$$

Equation 1 - CI ratio

With: C_F = Cost of fuel per kg

   C_T = Time-related cost per minute of flight

Time-related costs contain the sum of several components:
- ✈ Hourly maintenance cost
- ✈ Flight and cabin crew hourly wages
- ✈ Marginal depreciation or leasing costs

Two extreme values of CI can be identified, CI=0 and CI=MAX (value depends on hardware and software). CI=0 corresponds to a minimum fuel consumption mode allowing for maximum range. CI=MAX gives minimum flight time disregarding fuel economy. The cost index effectively provides a flexible tool to control fuel burn and trip time between these two extremes.

Industry sources suggest that airlines are currently failing to exploit the full economic potential of FMS's, since there's no actual effort in obtaining accurate CI values. Probably this happens because not everybody is fully aware of the importance of the Cost Index itself. Besides, realistic cost index calculations are not that easy to perform and require a transverse effort throughout the entire company.

Aircraft Performance Monitoring

Meaningful management of fuel saving programmes requires careful monitoring of the aircraft fuel consumption and of the effects of the measures taken. Notwithstanding the precautions,

the basic performance data produced by the manufacturers are sometimes not fully representative of the actual performance figures found in service, whether it is caused by airframe/engine degradation or by aircraft modifications.

Reasons for performance monitoring by operators include the following:

✈ Monitoring the fuel efficiency of the fleet

✈ Identifying high burners and ensuring that the company flight planning system and the FMS of the aircraft are using realistic data

✈ Verifying the effect of changes and modifications

✈ Diagnosing causes of performance deterioration

✈ Providing evidence in case of disagreement with manufacturers, on performance guarantees

Routine cruise performance monitoring by operators is performed in various ways and with different degrees of sophistication. However the preferred way of recording flight data is to use a FDR. Besides enabling to identify numerous parameters relating the aircraft, the FDR is also capable of recording engine parameters allowing a much broader performance study. One of the most practical examples of how an engine's proficient trend monitoring system can be of great help is to assess the possible benefits of a scheduled engine washing program, assisting in defining and fine-tuning the best time gaps, or flight cycles, between engine washes and even to assure that engines are kept under operating safety margins, despite a rigorous maintenance plan in place.

Operation Performance Study

The entire set of studies carried out in this work is based on all the data gathered by the GSV, relative to the operational year of 2008. This data consists of operational values and other types of information regarding all flights operated by both fleets. All data was handled with the help of Microsoft® Excel 2003 software which allows the extended use of *pivot tables*[4]. In order to validate the final results, some filters had to be set on the raw data. Entries relative to local flights (Arrival Airport being the same as the Departure Airport), without TOW, passenger figures or fuel values, single flights (only one sample) and flights with no information regarding the Captain were discarded, reducing the total number of entries to 27306 from the original 27664.

The series of metrics of different nature contemplated in this operational performance study aim to achieve a thorough understanding of the company's operation and its operational efficiency. It is also intended to show how a well-fitted data monitoring system which contemplates these different metrics, can be a powerful tool to identify certain performance trends and highlight

casuistic efficiency flaws, that in other case would pass unnoticed.

Routes

The different metrics used in this section analyze the operational performance of the most flown citypairs[5] of each fleet, due to the huge number of citypairs flown by PGA by both fleets. This way there is a representation of the most relevant citypair activity and it is possible to evaluate where a small change in operational procedures, can have greater impact on the operational performance.

Ground efficiency

All aircraft consume fuel on the ground at the airport while taxing, maneuvering to and from the gates, idling due to delays and by APU usage. All these situations represent unproductive fuel consumption, thus an inefficient use of fuel. To best quantify this inefficiency, the metric defined is the difference between block hours and actual time aloft (GE = BH – FH)

Graph 1 and **Graph 2**, show all flights departing LIS with approximately the same value of 0.31hr. This coherency in values leads to the conclusion that the main contribution for ground (in)efficiency is the departure airport, since several airports that compose different citypairs with LIS, originate significantly different ground efficiency values. Another conspicuous trend is that the greater and congested the departure airport is, the higher the ground efficiency value is, i.e., the more inefficient it is. The most notoriously GE aggravating airports are BCN, MAD and AMS.

In order to assess whether the weight of the aircraft affects the ground efficiency or not, the average payload is overlapped in both. The payload was chosen instead of the TOW, in order to deliberately neglect the weight of the FOB; only this way it is fair to compare two citypairs with completely distinct direct ground distance, with very similar average payload values, i.e., the comparison is made based on the actual productive load. It is easy to notice that the GE tends to follow the same trend as the Payload values and so this is in fact somehow affecting ground efficiency.
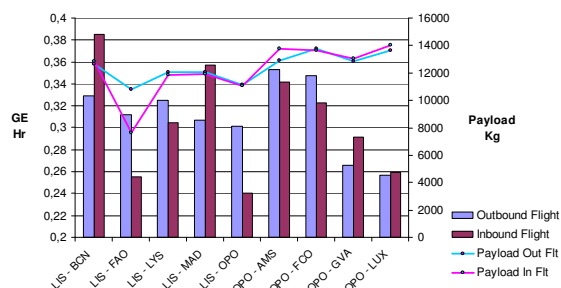
Graph 1 - Ground Efficiency by citypair - F100

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[4] Pivot table – Microsoft Office Excel tool that enables a parametric and changeable arrangement of large amounts of data.

[5] Flight connection between two different airports, with commercial purposes.
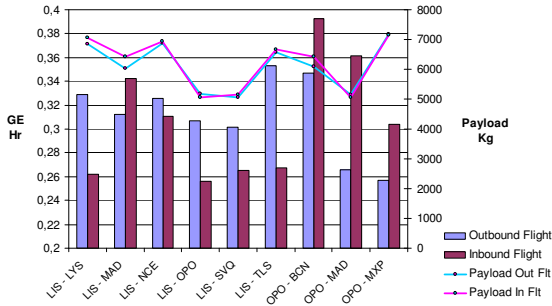
**Graph 2 - Ground efficiency by citypair - E145**

Fuel On Board

The loading of fuel before departure is done by following the company's policy on this matter, and it only seems logical that the company's fuel policy takes into account the length of the flight and the chosen alternate airport.

The bars in **Graph 3** and **Graph 4** represent the FOB Off Block and On Block sum of both legs of the flight. This is explained by the fact that the FOB values relative to the outbound leg are not bound to be compared with the ones of the inbound leg, since in an operational point of view the two legs differ significantly from each other. The FOB values are overlapped by the line PL/TOW and by yellow distance markers, which show for each citypair the direct ground distance per leg in NM. The PL/TOW (or the payload vs. takeoff weight ratio) is a metric itself, and in a practical explanation, might be described as the productive fraction of the TOW.
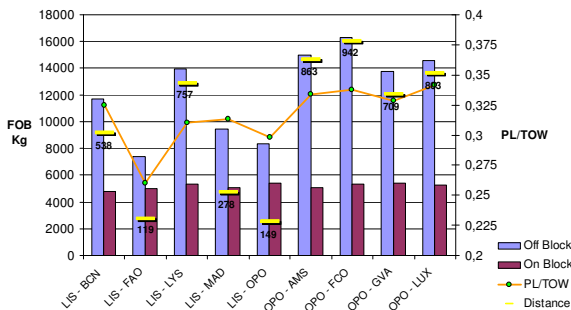
Graph 3 - FOB and PL/TOW by citypair - F100
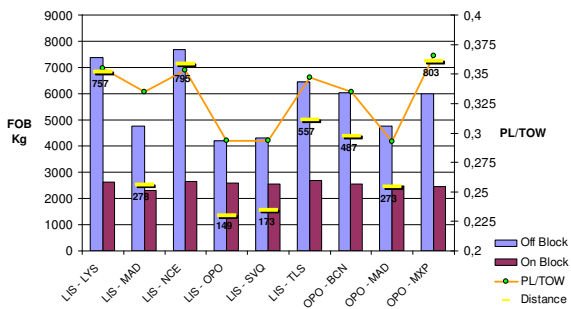
Graph 4 - FOB and PL/TOW by citypair - E145

It is quite notorious how the FOB Off Block follows the exact same evolution as the distance yellow markers. This comes as no surprise, as distance is the key factor on all fuel policies, for the longer the flight, the higher the flight time and the higher the trip fuel needed. The PL/TOW values also follow the trend of the other two (FOB Off Block and Direct Ground Distance).

On both fleets it's easy to observe the very consistent FOB On Block values. This is a direct result of putting into practice a studied fuel policy contemplating accurate reserve fuel calculations.

TFC and DFC

The TFC, or Time-based Fuel Consumption is a metric intended to quantify the global fight efficiency, created by convenience to allow a direct comparison between two flights, whatever the flight time and the takeoff weight. It takes into account the total burned fuel in the whole flight and the total flight time (FH), and their ratio is corrected for the TOW.

$$TFC = \frac{\dfrac{Total\ Fuel\ (Kg)}{FH\ (hr)}}{\dfrac{TOW\ (Kg)}{MTOW\ (Kg)}} = \frac{Total\ Fuel\ (Kg)}{FH\ (hr)} \times \frac{MTOW\ (Kg)}{TOW\ (Kg)}$$

Equation 2 - TFC

The dimensional analysis of this quantity renders Kg/hr as the final dimension. Similarly to the TFC, the DFC or Distance-Based Fuel Consumption was also created to quantify the global fuel efficiency, but in its turn based on ground distance covered in each flight. DFC dimension is Kg/NM.

$$DFC = \frac{\dfrac{Total\ Fuel\ (Kg)}{Distance\ (NM)}}{\dfrac{TOW\ (Kg)}{MTOW\ (Kg)}} = \frac{Total\ Fuel\ (Kg)}{Distance\ (NM)} \times \frac{MTOW\ (Kg)}{TOW\ (Kg)}$$

Equation 3 - DFC

However, the TFC is considered to be the most suitable metric for the job. Since the DFC calculated is based on the direct ground distance, it lacks a great deal of accuracy. Again, the most flown citypairs of each fleet were considered, and PL/TOW data is overlapped in the graphs to ease the analysis regarding its influence in flight efficiency. The direct ground distance covered in each citypair is also shown in yellow markers over the TFC bars.
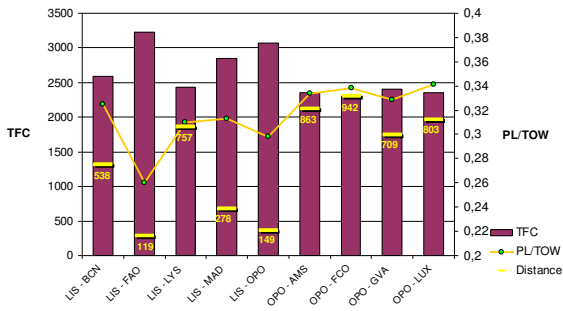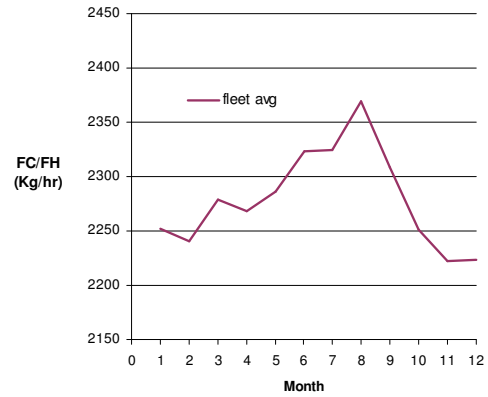
Graph 5 - TFC by citypair - F100
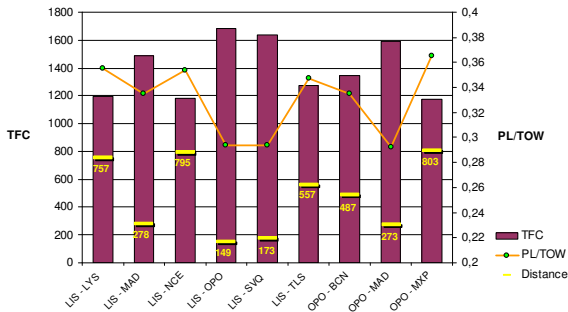
Graph 6 - TFC by citypair - E145

Graph 7 - FC/FH per month - F100
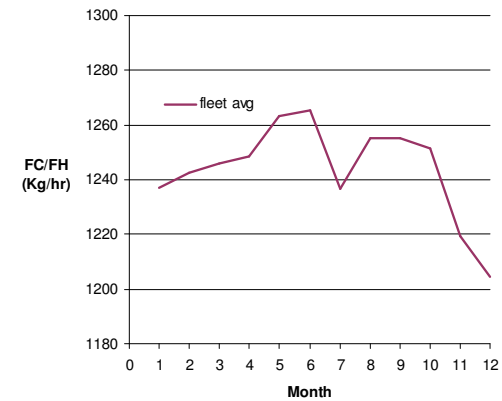

Graph 8 - FC/FH per month - E145

Graph 5 and **Graph 6** show a very coherent behaviour between the two fleets. The PL/TOW values have a matching evolution with the yellow distance markers, which in turn have the exact opposite trend of the TFC values. The shorter the flight the higher the TFC, in other words, the more inefficient the flight is. Two exceptions occur, in respect to the relation between PL/TOW and the direct ground distance, citypairs LIS-BCN and LIS-MAD (Fokker 100) have notoriously higher PL/TOW values than it was to be expected but these flights have higher average passenger occupancy than the others, justifying the higher payloads on these shorter flights.

Fleets

No machine is exactly like another, and aircraft, especially with their technological complexity, are no exception. This fact is even more relevant when one considers machines that have been operating for several years, and that may have been conditioned to different operational environments. The study of the performance of each aircraft is done by grouping the aircraft according to their respective fleet.

Graph 7 and **Graph 8** show both fleets' FC/FH on a monthly basis throughout 2008. For the Fokker 100 the summer months are clearly the most fuel-consuming ones being the more determining factors, the chosen FL as function of the winds aloft, the OAT and the TOW. The Embraer monthly FC/FH fleet average has a more inconsistent evolution. On the search for a suitable motive for this distinctive behaviour, the very own nature of the flights along the year was studied by dividing the entire universe of PGA flights in clusters of distances on steps of 200NM and comparing their respective representation on a monthly basis (Graph
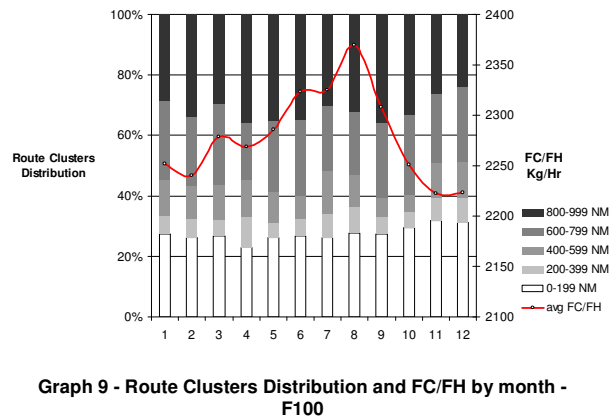
Graph 9 - Route Clusters Distribution and FC/FH by month - F100
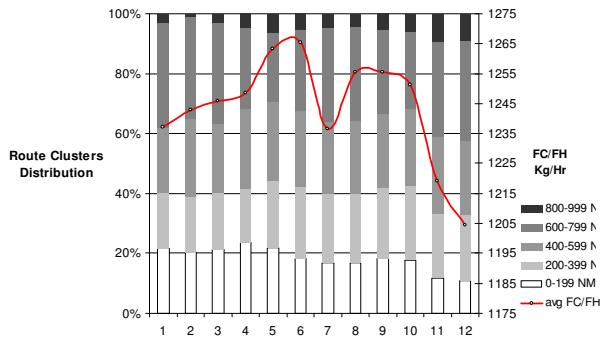
Graph 10 - Route Clusters Distribution and FC/FH by month - E145

These two graphs show a big difference between both fleet's route distribution, the Fokker fleet has half of its flights in the 0-199NM and 800-999NM clusters (evenly distributed between the two), while the Embraer fleet has only 10 to 20% of its flights in the 0-199NM cluster and has an, almost, symbolical representation on the 800-999NM cluster. It's still not perfectly clear though, if there's in fact a relation between the two metrics. To clarify this, an additional metric is created to properly relate the route clusters distribution with the hourly fuel consumption. The RDI, or Route Distribution Index, is the sum of the weighted percentages of the total flights in each cluster, by month:

$$RDI_{month} = 5 \times A_{month} + 4 \times B_{month} + 3 \times C_{month} + 2 \times D_{month} + E_{month}$$

Equation 4 - RDI

being,

$$A = flights_{0-199NM}(\%)$$
$$B = flights_{200-399NM}(\%)$$
$$C = flights_{400-599NM}(\%)$$
$$D = flights_{600-799NM}(\%)$$
$$E = flights_{800-999NM}(\%)$$

The practical meaning of the RDI is a means of quantifying the global nature of the flights on a certain month, within a given fleet. The weighted percentages of flights on each distance cluster tends to represent how aggravating in hourly fuel consumption, the different distance clusters are.
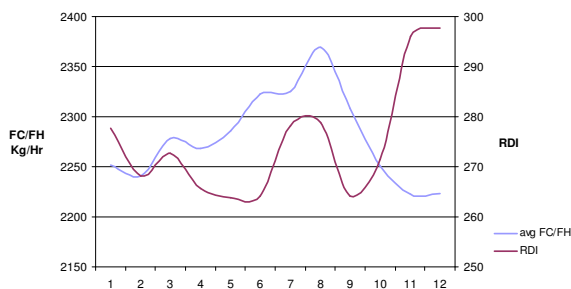

Graph 11 - RDI and FC/FH by month - F100
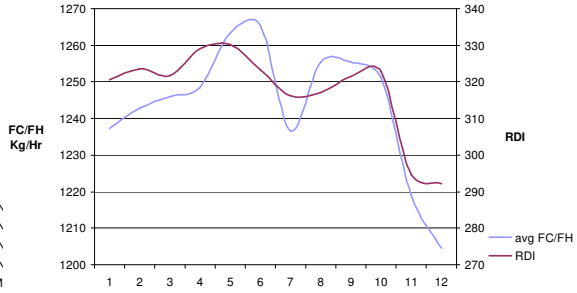
Graph 12 - RDI and FC/FH by month - E145

Making a qualitative analysis to these two metrics and their relation, it is possible to observe that Embraer's FC/FH and RDI curves are much more similar to each other than their Fokker's pairs. This evidences how one fleet is being more affected by the natures of the flights it is operating than the other. In this case, the Embraer fleet seems to be more affected than the Fokker fleet. This explains the sudden decrease in the Embraer's FC/FH average in July.
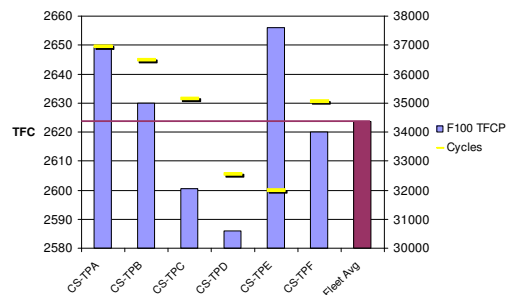
Graph 13 - TFC by aircraft - F100
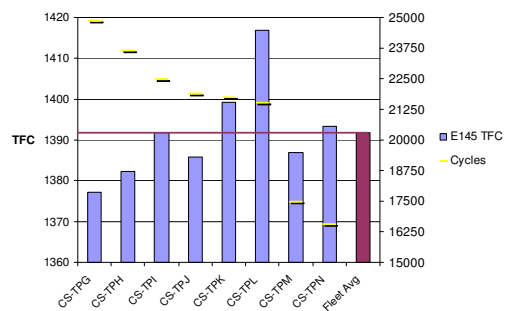
Graph 14 - TFC by aircraft - E145

The yellow markers on **Graph 13** and **Graph 14** intend to see if there's any relation between the aircraft's flight cycles and the performance degradation. At first, by looking at **Graph 13**, one can actually see that the yellow markers follow the TFC bars, with the exception of the CS-TPE, which could mean a possible situation of an aircraft expiring its airworthiness potential, requiring maintenance (whether it is time-related maintenance or not) in the nearby future. But considering **Graph 14** as well, this theory is shredded by the total opposite behaviour between the flight cycles and the TFC on the Embraers' figures. This doesn't mean that there is no relation

between the metrics; obviously there has to be some sort of degradation as an aircraft gets older (as it builds-up flight cycles). What it means is that the degradation suffered by an aircraft is not due to the airframe alone, but in fact it is related with the aging of all of the aircraft's elements; airframe, engines and systems. And so checking performance values against airframe flight cycles alone is worthless.

Flying Techniques

This section is dedicated to the study of the effects that one very important element of the aircraft has on its performance. It is an often forgotten element despite having a key role on an aircraft's operation, and that is the pilot. The pilot, more than a machine itself, is a human machine. So it makes sense that each pilot has its flying proficiency and techniques, resulting in different performance figures from one pilot to the next. The goal is to make good use of a study like the one presented, to enhance the average performance of a fleet's pilot roster. This can be achieved by identifying the ones that prove to be more efficient, and making good notice of what particular techniques they have in order to, and once proven so, establish standard operating procedures applicable to all pilots based on those same performance-friendly techniques.

Due to obvious space conditioning in this document, it is not possible to show the extensive graphs where each fleet's roster is represented along with its own performance figures. However these graphs were drawn and analysed and it became evident that due to considerable high standard deviation values, a statistical analysis was needed to clarify whether the results were mere statistical coincidence or the actual result of a relation between the different performance figures and the pilots. The test chosen was the ANOVA test, whose results are listed below:

Fleet	F	F_{crit}	$F > F_{crit}$
ERJ 145	2.651502	1.40537	Yes
F100	7.240922	1.504681	Yes

Table 1 - ANOVA Tests Results

By definition, since $F > F_{crit}$ is true in both fleets, but there is in fact a relation between the pilot and its own performance standing.

Performance Statistics and Prediction

This chapter also focuses on the study of the operational performance of PGA. However, it is done with a different purpose thus with a different methodology. In the previous chapter, all the gathered data was treated and organized in a way that allows different perspectives of PGA's operation: **Routes**, **Fleets** and **Flying Techniques** chapter tries to make a more forward analysis of PGA's operation, perhaps a more objective and raw perspective of the performance figures, without specifying anything but the aircraft type. This method intends to create a tool that, based on a statistical arrangement of the operational data, allows the prediction with an average level of precision of some of the performance metrics for any given flight in the scope of PGA's operations.

In this document the results of this study are presented in graphs where the different metrics are analysed as functions of the direct ground distance in a discrete form with 5 distance clusters of 200NM each. Information regarding trend lines and corresponding R-squared values follow each graph.

Flight Intensity

The graph below represents the cumulative sum of flights and the respective total fuel consumption. Each point refers to the cumulative sum of the referred values up to a certain distance cluster.
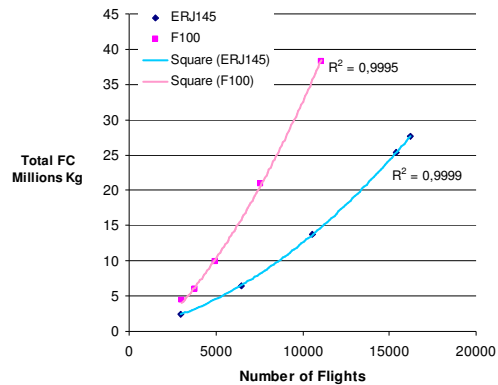
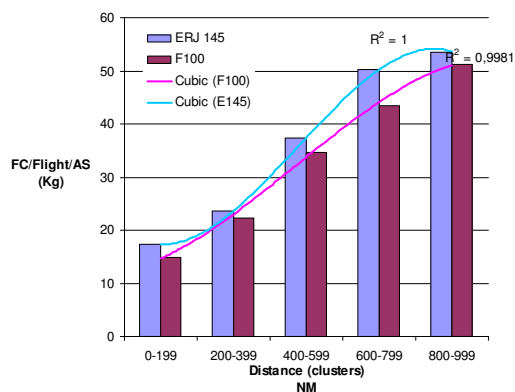**Graph 15 - Total FC vs. Flight Intensity**

$$FC_{E145} = 0.1768NF^2 + 1790.55NF - 3056259.72$$
$$FC_{F100} = 0.0742NF^2 + 484NF + 318333$$

Fuel Consumption

This section presents several graphs where Fuel Consumption figures are shown according to different perspectives, i.e., FC per different metrics.

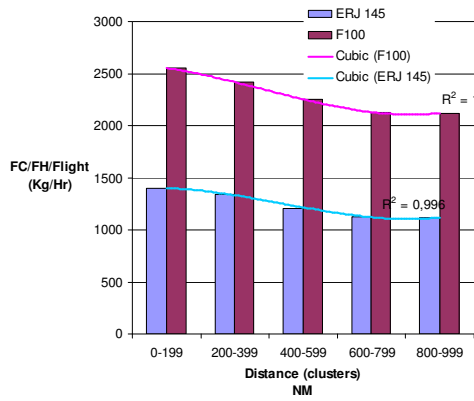### Fuel Consumption per Flight per Available Seat

Graph 16 - FC/Flight/AS

8

$$\left(\frac{FC}{Flight \times AS}\right)_{E145} = -1.4107D^3 + 12.203D^2 - 20.401D + 26.884$$

$$\left(\frac{FC}{Flight \times AS}\right)_{F100} = -0.4797D^3 + 4.0953D^2 - 0.5825D + 11.624$$

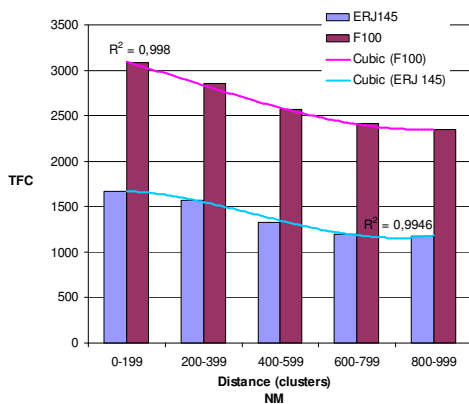**Fuel Consumption per Flight Hour per Flight**

Graph 17 - FC/FH

$$\left(\frac{FC}{hr}\right)_{E145} = 11.83D^3 - 95.737D^2 + 137.87D + 1344.3$$

$$\left(\frac{FC}{hr}\right)_{F100} = 12.128D^3 - 88.295D^2 + 45.882D + 2581.9$$

TFC

Graph 18 - TFC

$$TFC_{E145} = 20.661D^3 - 166.28D^2 - 235.51D + 1579.4$$
$$TFC_{F100} = 9.8199D^3 - 54.835D^2 - 160.43D + 3295.9$$

Flight Economy – a savings analysis

This chapter is dedicated to the study of how certain flight-related metrics, influence flight economy. This study was performed in an entirely different approach then the previous presented in this work; it follows a more practical methodology trying to include more of a pilot's perspective. In fact all data used in this chapter was collected from the FMS's of the Embraer and the Fokker. The main goal is to identify how two distinct flight strategies influence flight economy, specifically in terms of flight time and fuel consumption. This study's results are not shown due to space limitation; however the results are commented in each fleet's section. The sample flights chosen for the study were the most frequent flights in each distance cluster for each fleet:

Distance Clusters (NM)	Embraer 145	Fokker 100
0 – 199	LIS – OPO	LIS – OPO
200 – 399	OPO – MAD	LIS – MAD
400 – 499	OPO – BCN	LIS – BCN
600 – 599	LIS – NCE	OPO – GVA
800 – 999	OPO – MXP	OPO – AMS

Table 2 - Sampled citypairs for the savings analysis

With the FMS in a simulated ready-to-takeoff status, different scenarios were created changing the cruise Mach number (Embraer) or the CI (Fokker) and the configured TOW. Each scenario has its own flight time and fuel consumption figures, and it's those figures that are presented in the two sections below, one for each aircraft type.

Embraer 145

Since the FMS installed on the Embraer is a more simplistic piece of equipment than the one installed on the Fokker not contemplating cost index flight management, the different scenarios created for the Embraer study were based on different cruise Mach speeds. More specifically it is questioned what is the impact of reducing the typical cruise speed of the Embraer fleet from M=0.74 to M=0.72, and what is the result of flying with 200Kg less than the average TOW for each given flight.

The only noticeable difference (highlighted in green) in Fuel Consumption occurs with the reduction of the cruise speed to M=0.72 on the longest flight. However the values are limited to the precision of the equipment which goes no further than the hundreds of kilograms and so it is possible to conclude that ranging from the shortest to the longest flight there's a successive reduction on the Fuel Consumption values that refer to the cruise speed of M=0.72 when compared to typical M=0.74 speed.). It is also worth of notice that are no changes caused by the weight reduction. In spite of being obvious that there has to be some kind of difference in the amount of fuel burnt caused by the weight reduction, this means that it far less significant its direct impact that the one caused by simply reducing the cruise speed in M=0.02. Also, the delays caused by the speed reduction are not anywhere near a substantial value, not exceeding one minute, which in operational results have little, if any, importance.

Fokker 100

The same methodology was used upon the Fokker analysis. Although, the cost index flight management capability that the Fokker FMS

contemplates was used, instead of the more simplistic approach of just selecting the cruise speed. Three different cost index values were chosen in a way that the typical range of CI values could be covered, and the weight reduction scenarios were replicated from the previous section.

The same trends identified in the previous section are also observed are recurrent with the Fokker. The weight reduction does not have such a significant impact on fuel consumption reduction as the CI variation has. Again the FC FMS value has a limited precision to the hundreds of kilograms but already on the shortest flight it is noticeable a difference between the FC values corresponding to CI values of 15 and 30, fact maintained along all the sampled flights, as well as the fact that no difference is noticed between the FC values corresponding to CI=10 and CI=15. In the Fokker case the biggest Flight Time difference is eight minutes, which even though it is higher than the one noted for the Embraer it is still not that significant in an operational context with somewhat volatile flight schedules.

Conclusions

The dire economical situation the world has fallen to is unquestionable. Airlines worldwide are struggling for survival. Stay put is not an option. Challenges are ahead and everyone must face them or must dare the consequences.

Airline companies have to create financial viability and performance optimization is certainly a major mean to that end. Performance optimization provides the company with higher levels of efficiency, meaning less fuel consumption, less money spent, minor pollution trail, which is one of today's most serious concerns. Green policies are taking over all aspects of the industry, and there's nothing to be won by keeping one step behind in this matter. It is precisely the other way round. The EU ETS is mandatory and beginning to take shape, and operators who will not comply in time with their obligations, will be financially penalized.

The several fuel conservation strategies are very important elements of a performance optimization plan, and should not be disregarded. Their applicability and different implementation methodologies must be subjected to thorough investigation. That is also why a performance monitoring system is of the essence in such an organization. The several studies performed in this work, using all the different metrics, and by distinct approaches and methods, serve precisely, or wish to do so, to prove how useful a performance monitoring system can be, in identifying the different operational behaviours, trends, characteristics, of an airline. Knowing the operational nature of the company is the first step, to take any action, or undertake any plan or strategy towards performance optimization. This is common sense.

This work and any like it, in the author's humble opinion, is doomed to always left something undone, some metric not studied, some perspective not considered, and why not, some opinions left unheard. So it is only fair to suggest some topics to serve as motto for future work:

The development of a standardised trend monitoring system for both PGA's fleets engines.

The viability study of the inclusion of engine compressor washes in maintenance programs, using a suitable trend monitoring system.

Route and flight-specific Cost Index calculations for the Fokker fleet.

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Acronyms

ANOVA	—	Analysis of Variance
APU	—	Auxiliary Power Unit
AS	—	Available Seats
ASK	—	Available Seats Kilometre
BOW	—	Basic Operating Weight
CI	—	Cost Index
CG	—	Centre of Gravity
ETA	—	Estimated Time on Arrival
ETE	—	Estimated Time En Route
ETS	—	Emissions Trading System
EU	—	European Union
E&M	—	Engineering & Maintenance
FC	—	Fuel Consumption
FDR	—	Flight Data Recorder
FH	—	Flight Hour
FMS	—	Flight Management System
FOB	—	Fuel On Board
NAVAID	—	Navigational Aid
OAT	—	Outside Air Temperature
PL	—	Payload
RJ	—	Regional Jet
TP	—	Turbo Prop
TOW	—	Takeoff Weight
TSFC	—	Thrust Specific Fuel Consumption
SOP	—	Standard Operating Proceudure