

**DEVELOPING A “FLEET STANDARDIZATION INDEX”
FOR AIRLINE PLANNING**

Alexis George de Borges Pan

Department of Civil Aviation – DAC

M.Sc. Student in Transportation Engineering

Federal University of Rio de Janeiro, Brazil

Respicio A. Espirito Santo Jr., D.Sc.

Associate Professor

Federal University of Rio de Janeiro, Brazil

Quantifying subjective aspects is a difficult task that requires a great dedication of time from researchers and analysts. Nevertheless, one of the main objectives of it is to pave the way for a better understanding of the focused aspects. Fleet standardization is one of these subjective aspects that is extremely difficult to turn into numbers. Although, it is of great importance to know the benefits that may come with a higher level of standardization for airlines, which may be economical advantages, maintenance facilitation and others. A more standardized fleet may represent lower costs of operations and maintenance plus a much better planning of routes and flights.

This study presents the first step on developing an index, herein called “Fleet Standardization Index” or FSI (or IPF in Portuguese, for “*Índice de Padronização de Frotas*”), that will allow senior airline planners to compare different fleets and also simulate some results from maintaining or renewing their fleets.

Although being a preliminary study, the results obtained may already be tested to compare different fleets (different airlines) and also analyze some possible impacts of a fleet renewal before it takes place. Therefore, the main objective of this paper is to introduce the proposed IPF index and to demonstrate that it is inversely proportional to the number of different airplane models, engines and other equipment, such as avionics.

Authors’ contacts:

Eng. Alexis George de Borges Pan alexis@softhome.net

Prof. Respicio A. Espirito Santo Jr. respicio@momentus.com.br or respicio@pet.coppe.ufrj.br

1 INTRODUCTION

The need for standardization of the various items, equipment and characteristics of the aircraft composing an airline's fleet is a very discussed issue among aviation specialists and also among economists involved with the aviation industry. On the other hand, few studies have been done (or publicized) on this subject, leaving the particularities of fleet standardization covered in a mist of several complex issues that are poorly explored in the conventional literature.

In view of this, the primary objective of this paper is to start a broad analytical study and stimulate further follow-on studies on airlines' fleet standardization (fleet commonality issues), while considering the factors that influence this standardization and the benefits that can be granted from a higher level of it. For this, an initial effort is made to quantify the level of standardization of a given airline fleet, bringing both study and discussion from a subjective to an objective point of view.

Due to the somewhat pioneering characteristics found in the present study, the authors acknowledge that errors may occur during the conception and development of the formulations and assumptions herein made. For this, the authors welcome any contribution, suggestion and critics made on the purpose of continuing and improving the present study, since the primary goal is to contribute directly in the analysis and understanding of the challenging, complex and dynamic world of strategic airline planning.

2 FLEET STANDARDIZATION – DEFINITIONS AND INITIAL CONSIDERATIONS

When mentioning "fleet standardization", the first common thought points to a fleet composed of the same type of aircraft (i.e. from the same manufacturer and the very same model/variant) painted in the same color scheme and aligned on the apron, just as seen in several airline ads. Through this common view, having an Embraer ERJ-145 and an Airbus A319 in the same fleet means a great loss of standardization, mainly due to the different manufacturer. Nevertheless, when going deeper into the term of "fleet standardization", one should overcome the simple view of considering basic aircraft characteristics and incorporate engines, avionics, equipment, propellers, tooling and much more in his or her analysis.

This means that having several aircraft from different manufacturers or from a single manufacturer but of different variants may not pose a great deal, as long as these aircraft share the same engine manufacturer, for instance. As an example, four different Boeing airplanes (i.e.: 737-700, 747-400, 767-300 and 777-200) can be equipped with powerplants from a single manufacturer, even being the engines themselves different. Moreover, engines of the same family (using the same engine core) can be installed in various types of aircraft, from different manufacturers. An example is the Pratt & Whitney of Canada PT-6, used in the Cessna Caravan/Grand Caravan, the Embraer Bandeirante and the Bombardier (de Havilland) Twin Otter, just to mention a few.

In order to understand correctly the technical consideration of airline fleet standardization, we shall refer to the basics parts of an airplane.

2.1 Aircraft parts and components

When asking a child about what an airplane is, the answer would probably be somewhere near of “an airplane is a big vehicle that flies and has wings”. Complementarily, aviation enthusiasts would try to better distinguish the different parts of an airplane in their response on the same question, stating that an airplane is made of wings, fuselage and engines. But for the purpose of this study we shall refer to the classification used for project and maintenance as the most appropriate means in describing an airplane, pointing that it is composed of a cell, an engine-propeller system (the powerplant), avionics and other equipment.

The cell is what we could refer as being the “hull” of the aircraft, meaning all structures, the hull itself and assorted mechanical parts. It is important to notice that in this group, we will not include any interior-related item such as seats, bins, galleys, etc. The cell alone does not fly, but it is responsible for lift forces generation.

It is very common to consider the engine-propeller group and the engine alone the same item. In fact this error occurs due to the variety of jet aircraft used nowadays, where the propeller simply does not exist or does not make itself apparent. When mentioning the “engine-propeller group”, it will only make sense for turboprop or other propeller-equipped airplane, where an engine (piston or jet) is

responsible for rotating the propeller(s). The propulsion on jet aircraft is given entirely by the engine (turbojet or turbofan). For the purpose of this study, we will refer it all as “powerplant”.

The avionics group is the combination of all flight, engine and navigation instruments, together with all the electronic equipment on board, essential for the various regimes of flight the airplane has been certified. In this group we can mention the ADF, VOR and GPS as examples of navigation avionics, the VHF and HF radios as communication avionics and the N_1 (or EPR) indicator as an example of engine-monitoring avionics.

Finally, the last group is the one that combines all other items and equipment of the aircraft. This group is composed of so many different items that it can be referred as “others” without incurring in a serious error. Listed in this group are seats, galleys, interior panels, tires, etc.

2.2 Aircraft cell standardization

We can consider as having the same cell all airplanes from a single *family*, such as the Boeing 737-300/400/500, the 737-NG (-600/-700/-800/-900), the Airbus A318/319/320/321, and the Embraer 135/140/145. The differences between aircraft from a same family are usually few and usually relate to their length, capacity and powerplant variants (mainly thrust). Their piloting procedures and the maintenance procedures can be considered almost the same for simplification.. However, this approach must be taken with caution: it does not mean that all Boeing 737 have the same cell, as it is widespread known that the 737-200 is quite different from the -300/400/500 family, while both are different from the -NG family. This classification of separating through *families*, takes in account the design and the aerodynamics characteristics, indeed both quite similar (if not equal) to the entire family. In the basic approach and in the simplification herein used, it is of fundamental importance knowing how to classify the aircraft in *families*, or the findings of the present study will not be valid.

It is interesting to notice that, once all aircraft from a single family are usually operated almost on the same way, the “family classification” shown above immediately implies a substantial benefit when considering crew training programs. A crew trained to operate one type of aircraft within a given family can be easily switched to operate throughout all the other aircraft of that family.

2.3 Powerplant standardization

As mentioned before, the propeller is also a part of the engine-propeller group. On jet airplanes, we can say "engine" and "engine-propeller" indistinctly, because there is no propeller. As a follow-on to this preliminary study, a more detailed and complex analysis could consider fleets composed by all kind of aircraft (including aircraft with piston engines). In the present case, as a simplification, this paper will address the item "engines" as a whole, leaving the study of propellers' influence on standardization for the above mentioned follow-on, more detailed study. In view of this, as highlighted in the previous section, we will refer to the term "powerplant" only.

If it was possible to separate the powerplant from the cell, we could see some interesting situations. A single cell can be equipped with more than only one type of powerplant, and a single powerplant can be used with different cells, generating one or more of the following situations.

1. Same cell, same powerplant;
2. same cell, different powerplant;
3. different cells, same powerplant; and
4. different cells, different powerplant.

Low-aged fleets tend to be formed around situation #1. New entrant airlines, especially low-cost/low-fare carriers, tend to built their fleets aiming to extract the most positive results from this first situation. Middle-aged fleets, as the ones in a renewal process, can be commonly nested within situation #2. On the other hand, situation #3 is not commonly seen, but would be the case of a fleet composed by Boeings 707 and 737, that can be equipped with the same powerplant. Complementarily, situation #4 is more common on small airlines with a relatively small fleet, in particular all-cargo operators with few routes or operating cargo charter flights.

But, again, for the purpose of this preliminary study, let us concentrate solely on the powerplant. They will be classified not only in regard of its manufacturer and type, but also to the extent of what we will herein refer as variant or "dash", something like a 'sub-type'. This three-level classification is indeed complex, but it follows the same approach used for the two-level applied for the cell analysis, as will be seen on section 3.

2.4 Avionics standardization

The study of avionics standardization is much more complex than the aforementioned cases. This is in great part due to the great variety of instruments and electronic on-board equipment. In order to picture yourself in this complex scenario, imagine being the captain or first-officer of an airline operating a Boeing 737-300 registered BR-BR1 on day-one, and having to fly the next day another 737-300 (registered, say, BR-BR2), with instruments from different manufacturers and, worse of all, with these instruments mounted on different locations on the front and overhead panels. In the extreme, this could even lead to confusing the crew on a particular switch or on/off signal during an emergency situation, posing risks of catastrophic consequences. Moreover, maintenance personnel could also encounter problems with this confusing, multiple layout flight deck configurations while in the programming procedures of daily fleet maintenance.

This type of standardization can be easier to achieve as long as the carrier blocks a given batch of airplanes coming off the production line in direct sequence. In this case, even if not clearly demanded by the carrier, there is a tendency by the aircraft manufacturer to install avionics from a same supplier on all aircraft in that batch. In fact, a good level of standardization can be achieved within a same aircraft family when the avionics are at least of the same manufacturer or the same model, which is very much possible in several isolately purchased aircraft. However, nowadays only a few airlines are able to purchase batches of aircraft directly from the manufacturer, being the leasing of diverse aircraft from international lease companies one of the most common forms of fleet composition.

Being a preliminary study, this paper will not address the complex issues of the standardization involving the avionics group and the "others" group. We encourage other follow-on studies to address in detail these and other groups not listed in this paper.

2.5 Economical aspects of fleet standardization

It should be pointed out that using equipment from the same manufacturer may lead to significant savings in maintenance, spare parts inventory, tooling, training and in buyer-supplier negotiations. The target of the negotiation shall not be achieving short-term advantages, but mid- and long-term advantages. Brazilian carriers TAM and GOL are examples of it, the first with an almost all-Airbus

fleet (A319/320 and A330-200s, plus still a few Fokker 100s), and the second with a true all-Boeing 737NG fleet (737-700s and -800s). Although not being a target for the present paper, for a more detailed analysis of economical aspects of airline fleet standardization we recommend the approach put in discussion by Holloway (1997).

3 THE FLEET STANDARDIZATION INDEX (IPF)

Indexes (or indicators) are non-exact/non-precise tools to quantify a highly subjective aspect with no link to numerical data. Many indexes/indicators are commonly used in trying to allocate quantitative values poverty, development, customer satisfaction, and others. In spite of their existing limitations the use of indicators is continuously growing. In fact, if in one hand they are can be labeled as non-precise and non-exact, on the other hand they permit making direct and uncomplicated comparisons, which can be used, understood and discussed by almost any individual. Indexes are essential, for example, in the cost-benefit analysis, when evaluating the impact distribution of a project.

Comparing fleets is very difficult when the variety of types and models of aircraft and powerplants is such that allows almost infinite combinations between them. Moreover, discussing about fleet standardization is as difficult as comparing them. To assist in this difficult comparison task this paper introduces an index herein christened "Fleet Standardization Index", or IPF (for the initials in Portuguese of *Índice de Padronização de Frotas*).

As mentioned earlier, the formulation of the IPF is herein presented in its initial form of quantifying the level of fleet standardization. Despite this preliminary and simplistic approach, it is already possible to have a fair good idea about the status of airlines' fleets. In view of this, and considering its current preliminary format, the "Fleet Standardization Index" will be initially composed of two aspects: the standardization of airplanes' cells and powerplant. The development of the IPF formulation was made on a semi-empiric basis, starting with the following assumptions:

- The higher the number of different manufacturers of aircraft/powerplant, the lower is the level of standardization — consequently the IPF will be found proportional to the inverse of the number of manufacturers;

- The higher the number of different models (families) of airplanes/powerplants from the same manufacturer, the lower is the level of standardization — as seen above, the IPF is proportional to the inverse of the number of different models for each manufacturer;
- The same analogy can be used for the dashes (variants, sub-types) of powerplants — this put, the IPF is proportional to the inverse of the number of powerplant variants, for each model and manufacturer.

The two aspects shown above will lead to a pair of auxiliary indexes: the “Cell Standardization Index” (or IPC, in Portuguese) and the “Powerplant Standardization Index” (or IPM, in Portuguese). In further studies, other indexes could be added in the IPF determination (i.e.: IPA for Avionics, and IPOPI for Other Parts and Items). So, the initial formula for IPF is shown below:

$$IPF = \alpha_1 \times IPC + \alpha_2 \times IPM, \text{ where } \alpha_1 + \alpha_2 = 1 \quad (1)$$

The definition of α_1 and α_2 values will be the result of practical studies and surveys, when the researcher will be able to identify and measure the influence of each type of standardization on the IPF. As a matter of simplification and in order to obtain numerical results for this preliminary study, we will assume a case where the values are 0.6 to α_1 and 0.4 to α_2 . For this, expression (1) becomes:

$$IPF = 0.60 \times IPC + 0.40 \times IPM \quad (2)$$

The next and most important step is to obtain the equations for IPC and IPM. Considering the similarity between both them and again as a matter of simplification, we will address either one and then extrapolate the result to determinate the other. Later on we will mention some IPC and IPM formulas that were tried out by the authors, but were found to be non-effective.

3.1 Initial formulas

Initially, with the approach and considerations set on section 2, it was intended to pursue directly the formulation of indexes IPC (cell) and IPM (powerplant). However, a major concern arose when turning values that are proportional to the airplanes/powerplant quantities into a single expression. The intermediate solution adopted was to create partial indexes calculated for each manufacturer. These will be herein named “Cell Standardization Partial Index” (IPPC) and “Powerplant Standardization Partial Index” (IPPM, from the Portuguese abbreviations).

3.1.1 Cell Standardization Index (IPC)

The number of airplanes from each manufacturer is used as the ponderation factor of the index, being the number of models the main quantifying factor. Due to its inverse proportionality, the IPPC expression was obtained as:

$$IPPIC = \frac{\text{total number of airplanes from one manufacturer}}{\text{number of families from that manufacturer} \times \text{total fleet}} \quad (3)$$

With the IPPC in hand, tests were run in order to establish the correct formulation for the IPC. After several tests, the emerged IPC equation was:

$$IPC = \frac{\sum IPPC}{\text{number of manufacturers}} \quad (4)$$

In such a way, it was possible to ensure that the considerations seen in previous sections would be met, being the IPC inversely proportional to the number of manufacturers.

3.1.2 Powerplant Standardization Index

The same approach was used to develop the formulation for the IPM index. Nevertheless, as the powerplant considerations have a further level of detailing (different "dashes"/variants of powerplant available), an adjustment on IPPM was found to be necessary. This has emerged in another index, herein called "Model Specific Powerplant Standardization Index" (IPPMM). All expressions, for IPPMM, IPPM and IPM, are presented below.

$$IPPMM = \frac{\text{number of powerplants of a model}}{\text{number of dashes of same model} \times \text{total number of powerplants}} \quad (5)$$

$$IPPM = \frac{\sum IPPMM}{\text{number of models from a manufacturer}} \quad (6)$$

$$IPM = \frac{\sum IPPM}{\text{number of manufacturers}} \quad (7)$$

3.1.3 Practical use of the equations developed

In order to test and present a preliminary practical use of the above listed formulas, a sample airline "Air Studies" will be considered. This airline operates a fleet of aircraft from three different manufacturers, ALFA, BRAVO and CHARLIE, as listed on Table 1. The sample powerplants are listed in the right column of Table 1 and also on Table 2, on the sequence.

Table 1: Fleet operated by sample airline AIR STUDIES

Maker	Model	Qty.	Type	Powerplant
ALFA	ALFA-100	4	Twin jet	W-1-2
		3	Twin Jet	W-1-3
	ALFA-200	9	Twin Jet	W-7-2
BRAVO	B-1	2	Twin Jet	W-1-2
		8	Twin Jet	Y-90-F
	B-2	12	Twin Jet	Y-100-A
		25	Twin Jet	Y-100-B
	B-3	8	Twin Jet	Y-2000-Z
CHARLIE	CH-10	12	Twin Jet	Y-100-C

Table 2: Powerplant combinations used on sample airline AIR STUDIES airplanes

Manufacturer	Model	No. of variants/dashes	Total qty.
WALKER MOTORS	W-1	2	9 x 2 = 18
	W-7	1	9 x 2 = 18
YIELD AVIATION ENGINES	Y-90	1	8 x 2 = 16
	Y-100	3	37 x 2 = 74
	Y-2000	1	2 x 2 = 04

Calculating the IPC (Cell Standardization Index) for carrier Air Studies:

- ◆ Manufacturer ALFA: 2 different cell models, 16 airplanes total:

$$IPPC = \frac{16}{2 \times 83} = 0.096 \quad (8)$$

- ◆ Manufacturer BRAVO: 3 different cell models, 55 airplanes total

$$IPPC = \frac{55}{3 \times 83} = 0.221 \quad (9)$$

- ◆ Manufacturer CHARLIE: 1 cell model, 12 airplanes total

$$IPPC = \frac{12}{1 \times 83} = 0.145 \quad (10)$$

- ◆ The IPC for Air Studies is:

$$IPC = \frac{0.096 + 0.221 + 0.145}{3} = 0.154 \quad (11)$$

The next step, using Table 2 data, is to obtain the IPM for our virtual Air Studies carrier. Together with the calculated IPC, it will compose the IPF as shown in formula (2).

- ◆ Manufacturer Walker: 18 W-1 engines of 2 “dashes” and 18 W-7 engines of a single “dash”.

$$IPPMM_{W-1} = \frac{18}{2 \times 166}; IPPMM_{W-7} = \frac{18}{1 \times 166}; IPPM_{WALKER} = \frac{0.163}{2} = 0.082 \quad (12)$$

- ◆ Manufacturer YIELD: 16 Y-90 engines of a single type, 98 Y-100 engines of 3 types and 16 Y-2000 engines of a single type.

$$IPPMM_{Y-90} = \frac{16}{1 \times 166}; IPPMM_{Y-100} = \frac{98}{3 \times 166};$$

$$IPPMM_{Y-2000} = \frac{16}{1 \times 166}; IPPM_{YIELD} = \frac{0.389}{3} = 0.130 \quad (13)$$

- ◆ Follows the IPM for Air Studies:

$$IPM = \frac{\sum IPPM}{\text{number of manufacturers}} = \frac{0.212}{2} = 0.106 \quad (14)$$

◆ Finally, the IPF is obtained with formula (2):

$$IPF = 0.60 \times 0.154 + 0.40 \times 0.106 = 0.135 \quad (15)$$

It is important to observe that the result, alone, is of no meaning. However, when advancing to the next step of comparing the indexes for different airlines it would be possible to notice which carrier has a higher or lower level of standardization. Moreover, it can be used as a strategic tool in assisting and analyzing opportunities for fleet renewal.

3.2 Rejected formulas

In this section we will present some of the rejected formulas. Those herein listed were discarded because the results obtained were found to be incorrect and/or inconsistent in some particular situations. However, they were extremely valuable in the development of the initial formulas presented in section 3.1. As a matter of simplification, the formulas below will only be presented with its main discarding reason. Its development will not be presented.

3.2.1 First rejected formula

The following formula was the first to be rejected during the development of the indexes.

$$IPC = \sum IPPC \quad (16)$$

The reason for discarding formula (16) was the fact that the IPC (or IPM) would increase if the number of manufacturers had also increased. When analyzing the cell (or the powerplant) individually, having aircraft from more than one manufacturer, clearly the fleet will be less standardized, thus directly conflicting with what would be set in formula (16).

3.2.2 Second rejected formula

The tests following the previous rejection paved the way to discarding the equation shown below.

$$IPM = 1 - \sum IPPM \quad (17)$$

This formula solved the initial problem found with formula (16), but another problem of the same sort was then created. At that point the IPM (or IPC) increased with the increase in the number of

models, what would be also incorrect. The next step taken to re-analyze and run other tests came to solve this problem, leading to the correct formulas, presented in the previous sections.

3.3 General considerations for future development

As highlighted previously, the present approach does have limitations, the primary being that it does not yet consider the avionics and the "others" groups, both extremely relevant for a strategic fleet planning in the real complex world of airline planning. However, these limitations can be minimized with further analysis and research. The limitations identified during our study and some possible solutions are presented and discussed below.

The first drawback of the present preliminary development phase is the low capability of the IPF index in allowing planners not only to compare different fleets or situations but also its low capability in presenting them the correct feeling of quantity. In other words, a simple verification of the IPF value should be sufficient to understand the degree of standardization of that particular airline, which is still not the case with the equations herein depicted. In fact, the IPF index developed herein is sufficient only to conduct comparisons between different airlines (different fleets).

A more in depth mathematical approach, with the analysis of sample cases in a crescent or decreasing standardization sequence, could lead to a robust solution in helping correct the above mentioned drawback. Meanwhile, it is the understanding of the authors that the basis for calculation of IPF and related indexes and sub-indexes could be kept unchanged. The central point could be the linearization of results, and the task is to find a mathematical method to perform it. The authors have not yet used exponential factors, but it is believed that it could be a good way to achieve the desired results. Follow-on studies are being planned in this direction.

Another important limitation that do deserve attention is the numerical compatibility between IPC and IPM. At the present moment the values obtained for both seem to be incompatible in terms of dimensions, while the ponderation (weight) system used has been arbitrary. The follow-on study, now in its initial phase ("phase 2" of the entire original research project), is also being aimed at the necessity of the final IPF be obtained from comparable and compatible IPC and IPM values, to be

sure that the influence of cell and powerplant standardization are correctly balanced and accounted for. A reasonable form to pursue is to adequate \acute{a}_1 and \acute{a}_2 values in formula (1), thus pointing to a change in expression (2). Nevertheless, the basis for IPF calculation will still remain the same, as the results herein exposed remain valid for comparison purposes.

It is the understanding of the authors that a complex mathematical effort shall be employed to develop the final formula, which would then minimize to the maximum the limitations discussed and presented in the previous lines. This quantitative effort may include the measurement of influences and the linearization of both IPC and IPM.

The authors encourage other researchers to collaborate in this effort, even if departing from the original approach taken by the present study.

4 CONCLUSIONS AND CONSIDERATIONS

The Fleet Standardization Index (IPF), as presented in this pilot study, allows the quantification of a highly subjective aspect: the level of standardization between airline fleets. The comparison between two or more different fleets, from different airlines or simulating changes in an actual airline, can be made with the IPF.

However, some drawbacks have been identified by the authors in the formulation of the IPF itself and its components IPC (for the cell) and IPM (for the powerplant). Although limiting its effectiveness as a sole index (when not used to comparing different fleets or carriers), the problems identified can be minimized to a great extend. Follow-on studies to this research herein presented are already being drafted in order to realign the formulations. When this is achieved, it will permit the usage of the IPF index alone, without the need for comparison between different fleets and/or carriers (as the current model dictates).

For this, the authors endorse their encouraging towards other researchers to analyze and consider in more detail the multiple influential aspects of airline fleet standardization in order to verify the level of influence of each factor in the final airline IPF.

Bibliography

ANDERSON JR., John D. (1989) "Introduction to flight". 3rd edition, McGrawHill Book Company, Singapore.

HOMA, Jorge (1995) "Aeronaves e Motores", Editora ASA, Brasil.

SCHIAVO, A. C. (1998) "Conhecimentos Técnicos e Motores", ETA – Editora Técnica de Aviação, Brasil.

HOLLOWAY, Stephen (1997) "Straight and Level: Practical Airline Economics". Ashgate Publishing Company, USA.

RBHA 10 – Regulamento Brasileiro de Homologação Aeronáutica nº 10 (Brazilian Civil Aviation Regulation part 10), Brazilian Department of Civil Aviation, Brazil.

Authors' address:

UNIVERSIDADE FEDERAL DO RIO DE JANEIRO

Att.: Prof. Respicio A. Espirito Santo Jr.

Ilha do Fundão, Centro de Tecnologia, Bloco D – sala D209

Departamento de Engenharia de Transportes, DET/EP-UFRJ

Rio de Janeiro, RJ 21945-970

Brasil

respicio@momentus.com.br

respicio@pet.coppe.ufrj.br