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Cluster of aeronautical maintenance companies in Brazil

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1. Introduction

Brazilian domestic market for air transportation is the largest in Latin American and it has grown at a rate of 10% between 2003 and 2008 reaching over 50 million trips per year (McKinsey & Company, 2010). According to the McKinsey study, it is likely that this sector continues to grow at very relevant rates, given the expectation of income growth and therefore the demand for air transportation for poorer regions and classes in Brazil. Comparative data from August 2009 to August 2010 published by ANAC (National Civil Aviation Agency - Brazil) shows an annual growth around 34% in the demand for domestic flights and 28.5% for the external market. This air transportation growth requires an aircraft maintenance industry capable to support such an expansive process, without any prejudice to flight safety and continued airworthiness. Therefore, it is expected that Brazilian maintenance sector receives strong investments for years to come, generating important returns for the economy of Brazil. Under this scenario, it can be expected that the expansion of maintenance sector will contribute to Brazil's economic development through: increasing the participation of small and medium companies, due to the existence of small capital and technological barriers; the expansion of technical and technological job opportunities; the geographical spread of capabilities in maintenance services, with the entry of these activities into regions with lower levels of air traffic; encouragement to develop a local industry of aircraft spare parts.Thus, in order to support the decision making of investors and the development of public policies, it is necessary to build an overview of current conditions of the Brazilian aviation maintenance industry. Some of the papers found in the literature review explore the aircraft maintenance from other perspectives that seek to improve the efficiency of the sector. As an example, Nascimento (2006) and Rodrigues *et al*. (2010) study the costs perspective, while Ando and Costa (2004) and Papakostas *et al.* (2010) focus their efforts in the selection of maintenance strategies. Moreover, Vilela *et al.* (2010) examine the relationship of accidents with aircraft maintenance and operational safety recommendations. Other authors focus on classical maintenance subjects like systems analysis for failure diagnosis (Silva Filho *et al*., 2005); reliability and its relationship to cost control (Mata Filho *et al*., 1998) and maintenance planning (Samaranayake, 2006 and Samaranayake *et al.*, 2007). In this context, this paper aims to expand knowledge about the aircraft maintenance industry in Brazil exploring the

information provided by ANAC, with the main goal of building an overview which reveals the technical distribution of the Brazilian niches of capability. More specifically, this paper begins with an exposition of the basic concepts of aviation maintenance activity. Next, it is presented the Brazilian regulatory context, which circumscribes and certifies the activities that companies have the technical competence to perform. Finally, it was possible to analyze the concentration of different types of certification of aircraft repair station, regarding the certifications set obtained by them

2. Aeronautical Maintenance

2.1. Activities of aircraft maintenance

The aircraft maintenance can be divided into two activities that, despite being fully associated, possess different characteristics. The first activity is related to aircraft maintenance as single equipment, and the second activity concerns components maintenance that will serve as inputs to the first one. This distinction is necessary because the aircraft maintenance operations follow rules that go beyond the technical expertise necessary to perform maintenance activities. One example of this is the need for an intense struggle against the occurrence of human error when performing a task, because an aircraft, after maintenance, can not be tested to simulate flight conditions. However, this does not mean that human error in component maintenance is tolerated, but that the principles that guide their struggle are more closely related to the quality of the process itself than to issues of flight safety. Thus, as explained by Cheung Ip and Lu (2005), there is a difficulty in allocating specialized workforce in aircraft maintenance.

2.2. Regulatory Framework of Brazilian Aircraft Maintenance

The National Civil Aviation Agency – Brazil (ANAC), has as mission to promote safety and excellence in the civil aviation system, in order to contribute to the country's development and welfare of Brazilian society. Therefore, it is its responsibility to establish and monitor the implementation of regulations that govern the activities of maintenance companies. In regard to the activities of aircraft repair station, the ANAC classifies companies according to the type of services that they are able to perform. Thus, they may be aircraft, cells, engines, propellers, rotors, equipment and parts of those sets repair stations. To make this division possible, the ANAC has also established standards, classes and limitations on the maintenance activity. Thus, any company that wants to be classified as an aircraft repair station, should submit a request to the ANAC for a certification, specifying which aircraft, engine, propeller, rotor, equipment or component, they will perform the maintenance service. Based on Brazilian Civil Aviation Regulation (RBHA) 145 it is evaluated the technical and organization qualifications of the company and if confirmed these qualifications, a Brazilian Repair Station Certificate (CHE) is issued to that company.

It should also be noted that, airlines companies that possess RBHA 121 (Certification and Operation of Large Airplanes Domestic and Flag Operators) or RBHA 135 (Certification and Operation of Small Airplanes and Helicopter Domestic and Flag Operators) certification, do not need to certificate its repair stations according to RBHA 145, to perform services on its own fleet or, under contract, to another airline company also certified by those same RBHAs. The qualifications that are granted by these regulations are important to a better understanding of the maintenance sector in Brazil. Therefore, are described below the main requirements that they impose on this businesses sector.

2.3. Certification Technical Domain

The Brazilian Repair Station Certificates issued by the ANAC, refers to aircraft repair stations and they are based on patterns and classes as shown in Table 1.

Table 1 – Aircraft Maintenance Companies Patters and Classes.

Pattern	Class
Pattern C – Maintenance, modifications and cells repair	Class 1 - Composite structure aircraft, with maximum approved takeoff weight up to 5670 kg (aircraft) or 2730 kg (Helicopters) per aircraft model. Class 2 - Metal structure aircraft, with maximum approved takeoff weight up to 5670kg (aircraft) or 2730 kg (Helicopters) per aircraft model. Class 3 - Composite structure aircraft, with maximum approved takeoff weight over 5670 kg (aircraft) or 2730 kg (Helicopters) per aircraft model. Class 4 - Metal structure aircraft, with maximum approved takeoff weight over 5670kg (aircraft) or 2730 kg (Helicopters) per aircraft model.
Pattern D – Maintenance, modifications and aircraft engines repair	Class 1 – Conventional engines with up to 400 H.P., per model. Class 2 - Conventional engines with over 400 H.P., per model. Class 3 – Turbine engines, per model.
Pattern E – Maintenance, modifications, and aircraft propellers and rotors repair	Class 1 - Wood propellers, metal or composite, fixed pitch, per model. Class 2 – All other propellers, per model. Class 3 – Helicopters rotors, per model.
Pattern F – Maintenance and aircraft equipment repair	Class 1 - Communications and navigation aircraft equipment, per model Class 2 - Aircraft instruments, per instrument type. Class 3 - Mechanical accessories, aircraft electrical and electronics, per accessory model.
Pattern H – Specialized services	Single Class - Specific activities for the maintenance implementation that aeronautical authority upheld, per type service (e.g., nondestructive testing, floats, emergency equipment, rotor shovels, screen coating).

The certificates are issued considering patterns and classes, for example, a company “F1” certified means that it classified as Pattern F, Class 1.

Companies that are certified under the RBHA 121 or 135 are dispensed to be certified under the RBHA 145. However, the set of resources and facilities required for maintenance, preventive maintenance, modifications and repairs possessed or hired by the certified company can not be inferior to the set of facilities and resources required by the RBHA 145 to certificate an aircraft repair station for performing services of the same type at equipment operated by the certified company.

There are hundreds of repair stations certified as maintenance repair station in Brazil and in this work this scenario will be valued.

3. Research design and methodology

This paper is a part of a research work about Brazilian Aeronautical Maintenance Companies. The starting point has been a data collecting during two years (2009–2010). Data was collected through the National Civil Aviation Agency (ANAC) database. Methodology used based on the research terminology of Yin (1994) has been exploratory and descriptive based on a case study with both qualitative and quantitative approach. Exploratory studies are appropriate when the research problem is difficult to delimit, the problem is not well known and the available knowledge is not absolute (Yin, 2001). It was used additional methods of data collection to triangulate the data obtained from the ANAC database like ANAC regulations, specialized internet sites and literature review.

The purpose of this study is to expand knowledge about the aircraft maintenance industry in Brazil in order to gain a better understanding about the technical distribution of the Brazilian niches of capability, as well as identifies the profile of the certification cluster according to the technical domain of certification.

For achieving that purpose a exploratory study about the Brazilian Aircraft Maintenance Industry will be developed be developed by analyzing already established and known facts on a new perspective that permits to have a comprehensive understanding the Brazilian Aircraft Maintenance Industry.

3.1. Combined Certifications

The number of combined certifications (companies that possesses two certifications simultaneously) regarding to different classes and patterns of certifications are shown in Table 2. Diagonally it is possible to note the absolute total of certifications for each class and pattern and also the number of companies certified in more than one class and pattern of certificate are shown combining lines and columns.

Table 2: Combined certifications matrix

	C1	C2	C3	C4	D1	D2	D3	E1	E2	E3	F1	F2	F3	H
C1	86	83	1	5	55	7	6	12	13	1	6	3	31	19
C2	83	279	6	75	115	9	127	19	42	15	44	37	123	77
C3	1	6	9	1	1	0	7	0	1	2	3	3	7	6
C4	5	75	1	209	13	0	139	6	22	10	59	53	153	129
D1	55	115	1	13	134	8	38	20	28	6	8	7	75	37
D2	7	9	0	0	8	10	1	1	2	0	1	0	1	0
D3	6	127	7	139	38	1	244	9	38	15	71	66	179	135
E1	12	19	0	6	20	1	9	30	29	1	3	2	25	17
E2	13	42	1	22	28	2	38	29	60	5	18	16	49	34
E3	1	15	2	10	6	0	15	1	5	15	8	8	12	9
F1	6	44	3	59	8	1	71	3	18	8	112	98	104	70
F2	3	37	3	53	7	0	66	2	16	8	98	106	100	62
F3	31	123	7	153	75	1	179	25	49	12	104	100	346	202
H	19	77	6	129	37	0	135	17	34	9	70	62	202	260

Therefore, data in Table 2 demonstrate that, from the total of 279 certificates issued to the C2 type, 115 were issued for aircraft repair stations that also have certifications D1 type. In the same way, from the total of 106 certifications issued for the F2 type, 100 were issued for aircraft repair stations that also have certifications F3 type. However, according to Fávero (2009), an important aspect to be considered in a cluster analysis is the use of variables with

different measures, which can lead to a distortion of the group structure. This influence of variables different magnitudes can be solved with variables standardization.

Thus, the data presented in Table 2 were standardized by the maximum amplitude method, which attributes to each variable the maximum value of 1, and is calculated by dividing the value of each variable by the maximum value of the class analyzed. Table 3 shows those standardized values of the variables obtained from Table 2.

Table 3: Standardized Combined Certifications Matrix

	C1	C2	C3	C4	D1	D2	D3	E1	E2	E3	F1	F2	F3	H
C1	**1,000**	**0,965**	0,012	0,058	0,640	0,081	0,070	0,140	0,151	0,012	0,070	0,035	0,360	0,221
C2	0,297	**1,000**	0,022	0,269	0,412	0,032	0,455	0,068	0,151	0,054	0,158	0,133	0,441	0,276
C3	0,111	0,667	**1,000**	0,111	0,111	0,000	**0,778**	0,000	0,111	0,222	0,333	0,333	**0,778**	0,667
C4	0,024	0,359	0,005	**1,000**	0,062	0,000	0,665	0,029	0,105	0,048	0,282	0,254	0,732	0,617
D1	0,410	**0,858**	0,007	0,097	**1,000**	0,060	0,284	0,149	0,209	0,045	0,060	0,052	0,560	0,276
D2	0,700	**0,900**	0,000	0,000	**0,800**	**1,000**	0,100	0,100	0,200	0,000	0,100	0,000	0,100	0,000
D3	0,025	0,520	0,029	0,570	0,156	0,004	**1,000**	0,037	0,156	0,061	0,291	0,270	0,734	0,553
E1	0,400	0,633	0,000	0,200	0,667	0,033	0,300	**1,000**	**0,967**	0,033	0,100	0,067	**0,833**	0,567
E2	0,217	0,700	0,017	0,367	0,467	0,033	0,633	0,483	**1,000**	0,083	0,300	0,267	**0,817**	0,567
E3	0,067	**1,000**	0,133	0,667	0,400	0,000	**1,000**	0,067	0,333	**1,000**	0,533	0,533	**0,800**	0,600
F1	0,054	0,393	0,027	0,527	0,071	0,009	0,634	0,027	0,161	0,071	**1,000**	**0,875**	**0,929**	0,625
F2	0,028	0,349	0,028	0,500	0,066	0,000	0,623	0,019	0,151	0,075	**0,925**	**1,000**	**0,943**	0,585
F3	0,090	0,355	0,020	0,442	0,217	0,003	0,517	0,072	0,142	0,035	0,301	0,289	**1,000**	0,584
H	0,073	0,296	0,023	0,496	0,142	0,000	0,519	0,065	0,131	0,035	0,269	0,238	**0,777**	**1,000**

In Table 3, it is possible to verify the different similarity degrees between different classes of certification. The closer the values are to 1, the higher is the level of composed certifications. In order to a more accurate analysis it was applied generating clusters method.

3.2. Certifications Cluster

In this study, data were classified by using information from the standardized data. To perform the hierarchical analysis of clusters generation, it was chosen Euclidean distance with subsequent application of the Ward method, due to the quantitative analysis. The Figure 1 presents the aeronautical maintenance homologation certificates cluster dendrogram by pattern.

When the clusters are observed, it can be verified that in the first cluster, from left to right, the E3 pattern (Helicopter Rotors) is in an isolated branch, situation justified by its specificity. Still in the first cluster, the “D3” patterns (turbine engines) and “F3” (aircraft mechanical, electrical and electronic accessories) are in the same branch, which is also justified as the turbine engines have a large quantity of accessories that also need specific maintenance. The “D3-F3” pattern branches are associated to the “C4-H” pattern branches (“C4” related to metallic structure aircrafts, with maximum takeoff approved weight above 5670 kg (airplane) or 2730 kg (helicopters) and “H” being related to specific maintenance in activities execution). This makes sense as larger aircrafts are the ones that commonly have turbine engines.

In the second cluster, it can be observed that the “C3” pattern (combined structure aircraft, with maximum takeoff approved weight above 5670 kg (airplane) or 2730 kg (helicopters)) are in a specific branch, clustered, however, with “F1 and F2” patterns (aircraft communication/navigation equipments and aircraft instruments, respectively). Taking into

account that combined structure aircraft are, normally, more modern and also that more modern aircraft are the ones which have more communication/navigation equipments and instruments, that agglomeration in the second cluster is coherent.

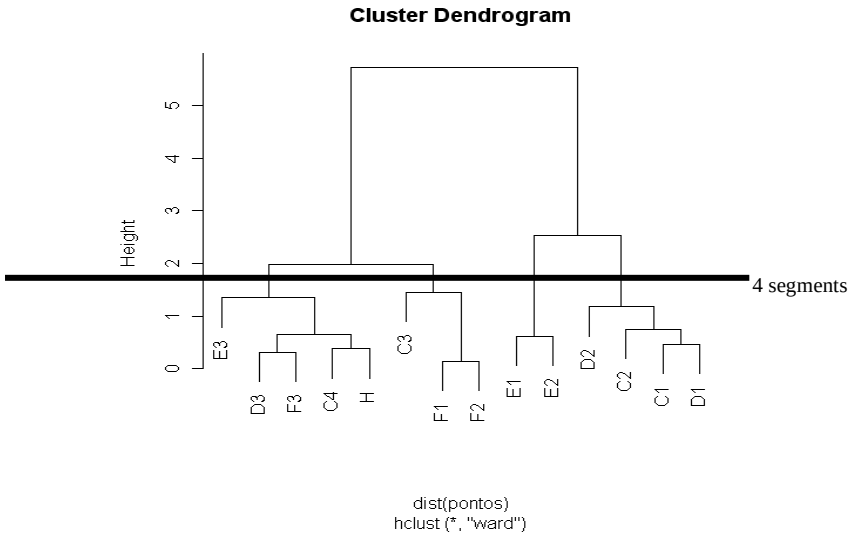

Figure 1. Certifications cluster dendrogram

In the third cluster, it is possible to identify a certification cluster for propellers maintenance certifications ("E1 and E2"), which is justifiable by itself. In the fourth cluster, are concentrated companies certifications that perform maintenance in conventional engines, "D1 and D2" pattern, along with "C1 and C2" patterns, associated to modifications and repairs of smaller aircrafts cells, which consequently use, generally, conventional engines. This analysis, from the dendrogram, enabled to find out that the aeronautical maintenance companies are trying to certify themselves into groups and maintenance classes patterns that will possibly increase their services scope for certain types of aircraft.

4. Final Considerations and Further Research

This study sought to bring this aircraft maintenance subject into scientific discussion, and from primary data collected, to evaluate aircraft maintenance companies in terms of technical distribution and also to study the information about the companies' certification type, that also exposes their technical training. This work shows a snapshot of the current maintenance and reveals an area with potential for significant growth driven by expected growth in the Brazilian air transportation. The data here presented, represent a case study of Brazilian aircraft maintenance industry, consequently it is a descriptive approach with no pretension of generalization for the aircraft maintenance situation as a whole. However, we recommended that there are some points that can be discussed from the analysis in this work. Considering that specialization and technology training required to perform "D" and "F" services are

significantly higher than those required to perform “C” services, Is it right to assure that other industries have technologically lagged behind Brazilian aircraft maintenance industry? Does the volume service for “C” pattern surpass those demanded by the “D” and “F” services? The second point to be explored, regards to combined certification that have different patterns. Is that a usual practice in international aircraft maintenance scenario? What is the boundary in which composed certifications could affect the development of technical competences required from each pattern? Thus, it is necessary a better verification on developed practices in this sector and the observation about how the actors in this scenario are enabling themselves organizationally and technically, considering the great importance of the subject.

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