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A qualitative study of outsourced aeronautical maintenance: The case of Brazilian organizations

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ABSTRACT

The outsourcing of aeronautical maintenance has been criticized for the quality of services offered. According to the literature, airlines have contracted repair stations to perform maintenance activities on their aircraft or parts when attempting to optimize resources (time, facilities, personnel, money). The attempt to reduce costs in maintenance activities and regulatory deficiencies can lead to maintenance management practices that could threaten equipment airworthiness. Therefore, the aim of this research was to evaluate whether outsourced aeronautical maintenance is aligned to common industrial maintenance management practices. To achieve this goal, qualitative exploratory research was conducted on Brazilian repair stations. For data collection, a questionnaire was developed based on seven factors related to aircraft maintenance. The data revealed that a mismatch exists between the best maintenance management practices and expected repair station performance.

1. Introduction

Maintenance activities are the backbone of successful aircraft operations (Bazargan, 2015). In the aviation industry, maintenance is highly regulated by various global and local airworthiness authorities (i.e., the European Aviation Safety Agency (EASA), Europe; the Federal Aviation Administration (FAA), the United States; Agência Nacional de Aviação Civil (ANAC), Brasil; and others) (Regattieri et al., 2015). Under such a regulatory context, the main role of the maintenance, repair, and overhaul (MRO) organization for an airline is to provide a fully serviceable aircraft when required by the operators at minimum cost and optimum quality (Al-Kaabi et al., 2007). While planning maintenance activities, an airline can choose to perform these activities "in house," or outsource them. However, planning and coordinating aircraft MRO tasks is complicated because each aircraft has thousands of serviceable parts (Czepiel, 2003), which are arranged in complex and close connections that could eventually lead to system accidents (Arminen et al., 2010). In view of the stringent requirements set by regulatory ambiance and of the limited set of internal resources, such as available labor force, infrastructure hangar, and business scope, etc., an airline may choose to partially outsourced maintenance activities to a MRO organization or specialized repair station to execute activities that require more infrastructure or specialization (Al-Kaabi et al., 2007). Outsourcing MRO enables airlines to avoid significant capital investment in facilities, equipment, and inventories of parts and components (Tang and Elias, 2012). Repair service of an aircraft item (a spare part) is usually provided either by the original equipment manufacturer (OEM) that manufactures the equipment (Selçuk, 2013) or outsourced to a certified maintenance service supplier for that specific item. The tasks to be outsourced vary from company to company and aim to keep the aircraft available to fly for the longest period possible at an acceptable cost, given the security matters and in accordance with the regulatory standards of the country.

However, according to Pettersen and Aase (2008), airline companies have outsourced their operational maintenance functions, purchasing them from the lowest bidder. Thus, it is likely that safety issues have occurred due to this outsourcing. Quinlan et al. (p. 285, 2013) found the following three sets of contributory factors

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adversely affecting safety outcomes: "First, economic and financial pressures on contractors often led to corner-cutting or unsafe practices concerning to safety. Second, subcontracting was linked to hazardous forms of disorganization including weakened induction, training, and supervisory regimes. Third, regulatory failure including insufficient regulatory coverage, implementation, and enforcement contributed significantly to poorer safety outcomes." It should be noted that Quinlan et al. (2013) identified that those problems have affected a wide set of countries, which have different regulatory regimes. To address aviation maintenance safety factors, the International Civil Aviation Organization (ICAO) developed Annex 19 to the Convention on International Civil Aviation, dedicated expressly to safety management (ICAO, 2013a). In fact, it is expected that improving regulation, auditing and enforcement may deter unsafe aviation maintenance practices.

However, a group of factors exists relating outsourcing to hazardous forms of disorganization that could be associated with the lack of good management practices for promoting aviation maintenance safety. Czepiel (2003) analyzed a limited collection of information obtained from interviews with both U. S. airlines and repair stations, mainly regarding their respective quality assurance departments. This study notes that, for the case of some outsourced repair stations, their standards about personnel safety procedures and hangar equipment were well below that of air carrier maintenance. Czepiel (2003) also suggests that outsourced repair stations have not yet reached airline standards for developing maintenance human factors and maintenance resource management programs. These arguments reinforce the idea that, to overcome such disorganization mentioned by Quinlan et al. (2013), it is necessary to establish a good set of aircraft maintenance management practices that address safety problems while improving adherence to legal requirements and management practices that promote safety.

Therefore, based on these arguments, the following research question arises: "Are outsourced aircraft maintenance organizations implementing appropriate safety and good practices for aeronautical maintenance management?"

This study aims to answer the question and assess the maintenance management systems of aeronautical repair stations in Brazil regarding their alignment with aeronautical maintenance management practices (MMP) and identify which managerial factors are more relevant for the repair stations. A qualitative exploratory study design is used to investigate MMP in Brazilian subcontracted organizations. To precede this assessment, based on literature review, seven maintenance management factors are generated that affect aeronautical maintenance outcomes. Guided by these factors, a questionnaire with a five-point Likert scale was applied to Brazilian aeronautical maintenance organizations to collect data.

This paper begins with a theoretical framework (Section 2) about aeronautical maintenance and the Brazilian context of aeronautical maintenance, and Section 3 covers the methodology. Section 4 describes the results and discussion. Finally, conclusions are presented in Section 5.

2. Theoretical framework

2.1. Aeronautical maintenance

The type of maintenance to be performed on aircraft, and its equivalent costs, vary according to certain factors such as the generation of the aircraft, age, frequency of use, fleet composition, route of aircraft operation, operating practices of the company when periodically checking the aircraft maintenance philosophy of the company and maintenance planning versus maximizing the availability of the aircraft (Kinnison, 2004). Maintenance activities can be performed "in house" by the operating company or can be outsourced (Machado et al., 2015). Depending on the conditions of the airline, such as available labor, infrastructure hangar and business scope, the company may choose to partially outsource maintenance activities, including those that need more structure or specialization. The tasks to be outsourced vary from company to company, but the aim is to keep the fleet of aircraft flight available for the longest period of time at the lowest cost, given the safety questions and in accordance with the regulatory standards of the country (Al-Kaabi et al., 2007; Czepiel, 2003; Gregson et al., 2015; Quinlan et al., 2014, 2013). ICAO defines the concept of safety within the context of aviation as "the state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and safety risk management" (ICAO, 2013b).

An Aircraft Maintenance Organization (AMO) is often referred to as maintenance, repair and overhaul (MRO) (Shanmugam and Paul Robert, 2015). The main role of the MRO of an airline is to provide a fully serviceable aircraft when it is required by the operators at minimum cost and optimum quality (Al-Kaabi et al., 2007). It is reasonable to expect that all MRO have a robust maintenance management system.

Maintenance management is a systematic approach to planning, organizing, monitoring and evaluating maintenance activities and their costs (Abudayyeh et al., 2005). Knotts (1999) stated, in the aviation context, that maintenance activities are those actions required to return an item to working condition, including services, repairs, modifications, inspections and determination of the current state of the aircraft or its parts, making maintenance management more complex. According to Holloway (2008), aircraft maintenance accounts for a major cost of airline operations, significantly contributes to the security, availability, pricing of passenger travel, and integrity of business operation (Regattieri et al., 2015). Maintenance should aim to ensure the aircraft (or fleet) is in good condition, both internally and externally, when and where it is needed and at the lowest cost, while complying with all security variables (Al-Kaabi et al., 2007; Belien et al., 2012; Czepiel, 2003). One of the practices aimed at keeping costs competitive is the outsourcing of aircraft maintenance, repair, and overhaul (MRO), either domestically or to foreign countries (Tang and Elias, 2012). The treatment of costs involved with maintenance and repair overhaul (MRO) are generally calculated using the Available Seat-Mile (ASM), varying according to the use of the aircraft, its occupation and the efficiency of maintenance activities (Holloway, 2008). An alternative way of examining these maintenance values is calculating the total cost of ownership divided by block-hour (the extent of aircraft use that considers the period between closing of the door of the aircraft at the gate to takeoff and opening the door of the aircraft door upon gate arrival) (Kinnison, 2004). Therefore, despite the importance of safety and the quality for aircraft maintenance, cost has been a major factor reinforcing the statement that the best maintenance management practices are being neglected, for example, due to the cost reduction.

Based on the above information, it is clear that aircraft maintenance must ensure the availability of aircraft, infrastructure, schedule, cost, quality, safety and compliance with regulatory agencies.

2.2. Brazilian context of aeronautical maintenance

The National Civil Aviation Agency (ANAC) aims to promote the safety and excellence of the civil aviation system to contribute to the development and welfare of Brazilian society. Therefore, it is incumbent to establish and oversee compliance with the regulatory

framework governing the activities of maintenance companies (ANAC, 2015).

Concerning the activities of aircraft maintenance organizations, the European Aviation Safety Agency (EASA), the Federal Aviation Administration (FAA), and the Agência Nacional de Aviação Civil (ANAC) classify companies according to the type of services they can perform, and by specifics regulations, namely, EASA Part 145; Federal Aviation Regulation, FAR 145; and Brazilian Regulation of Civil Aviation, RBAC 145. The type of service can be, in general, for the airframe, power plant, propellers, radios, instruments, or accessories. ANAC also set standards, classes and limitations for maintenance activities for these division maintenance categories. Thus, any company that wants to be classified as a repair station or MRO must submit a request to ANAC for approval, specifying the part of the airframe on which maintenance will be performed. Based on the Brazilian Regulation of Civil Aviation (RBAC) 145, technical and structural organization qualifications of the repair station or MRO are assessed, and, if competence is confirmed, the organization is issued a certificate of Aeronautical Product Maintenance Organization (ANAC, 2014). These requirements established by RBAC 145 reveal the importance of managing maintenance organizations. RBAC 145 was developed based on American Federal Aviation Regulation, FAR 145, and has exactly the same structure.

However, according to Fedel et al. (2006), aviation-related organizations currently utilize a cost containment culture with the goal of increasing or recovering profit margins, so the development of organizational culture geared to security is not viewed with the same importance. This reinforces the objective of this research to assess the management systems of Brazilian aircraft maintenance companies.

3. Method

3.1. Model and sampling

This study uses qualitative research to explore the status of maintenance management practices in aircraft maintenance organizations. Cooper and Emory (2003) state that both qualitative and quantitative techniques are applicable in exploratory studies; although, exploration relies more heavily on qualitative techniques. Barratt et al. (2011) define a qualitative study as an empirical research that primarily uses contextually rich data from bounded real-world settings to investigate a focused phenomenon. In fact, contrasted to quantitative research which relies on measurement and bracketing according to close-ended categorizations, qualitative research is central to the openness of the researcher to sensory impressions and subjective interpretations (Andersen and Kragh, 2010).

Brazil has approximately 500 maintenance companies certified by ANAC and in compliance with the RBAC-145 regulation (similar to FAR 145). The target of this study is limited to 130 certified repair stations that participate in aircraft maintenance activities in Brazil. This sample size is obtained after a meeting with experts at the Institute of Industrial Promotion and Coordination (IFI) who are responsible for the coordination of the aeronautical industry in Brazil. In planning for data collection, it was important to obtain the maximum possible questionnaire return; however, at the end of data collection, only 27 valid questionnaires were returned.

The selected repair stations are distributed in different Brazilian regions, which allowed different profiles to be analyzed. This geographic factor influenced the decision of how to best collect data (via questionnaire). Because the repair stations participating in the research were located in distant places, it was easier to retrieve questionnaires sent by e-mail rather than by personal interview (Machado et al., 2015).

3.2. Data collecting tool

To expand the data collection instrument, the method proposed by Campenhoudt and Quivy (1992) was used where, from a "concept" (in this research, maintenance management practices), dimensions are developed (called factors), which are broken down into indicators (called affirmative issues).

Then, to prepare the questionnaire, the following steps were conducted. First, based on the literature on maintenance management practices, seven factors were proposed to evaluate the maintenance management practices of the repair stations selected for the study. These seven factors are listed below. *Legal requirements*: the certification of airlines or repair stations by airworthiness authorities and the periodic inspections to ensure continued compliance with safety regulations (Czepiel, 2003). *Planning and programming*: maintenance systems need effective task or job planning and programming (Gopalakrishnan et al., 2015; Papakostas et al., 2010). *Information management*: control of all of the written or computerized source data that maintenance technicians require for completing a task or job (Boeing/ATA, 1995; Rankin et al., 2000). *Maintenance resources*: equipment, tools, parts, and human factors required to work together to promote safety (Czepiel, 2003; Taylor, 2000). *Support and control*: spare parts inventory and control of suppliers (Gu et al., 2015; Kilpi et al., 2009). *Safety*: management device using proactive and reactive tools that rely on safety performance with a focus on processes and identifying hazards and risks while mitigating safety risks (Gerede, 2015a, 2015b; Gregson et al., 2015). *Human resources*: organizational structure that facilitates assigning the right people to the job as well as applies appropriate job-aids and quality management systems to promote maintenance service quality (Cholasuke et al., 2004).

RBAC 145 (ANAC, 2014), EASA 145 (EASA, 2012) regulations and the standard AS9100 (AAQSC, 2009) in addition to the literature were used to prepare affirmative issues that composed the questionnaire. Fig. 1 presents a development framework of the questionnaire.

The final version of the questionnaire had 59 affirmative sentences, i. e., Q1 to Q59 (Appendix 1). The available options regarding data generation and treatment generated by the research mean were presented, and the answers were defined as qualitative rather than numerical, in accordance with the five-point Likert scale.

3.3. Data analysis and interpretation

Qualitative research is an inquiry process that draws data from the context in which events occur in an attempt to describe these occurrences. Qualitative methods are used to describe, decode, and advance the understanding of intertwined past, present, or future eclectic data (Hlady-Rispal and Jouison-Laffitte, 2014). Primarily, qualitative research relies on observational data, in-depth case

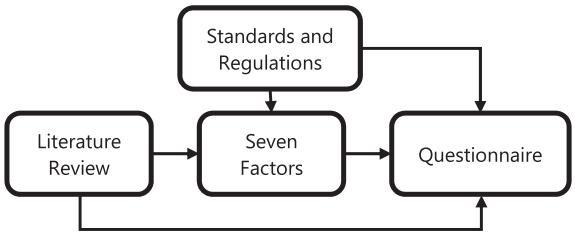

Fig. 1. Framework for questionnaire development.

studies, grounded theory, participant observation studies, etc. aimed at conceptual theory development (Narasimhan, 2014).

Of the 130 questionnaires with 59 statements, 27 were returned and were considered valid. All information collected was compiled into a spreadsheet. For each statement, a qualitative analysis of organizational compliance with each statement was made. Then, each of the seven factors was evaluated, considering all of the affirmatives issues. The research findings were explained and interpreted based on the literature review.

4. Results and discussion

The results in each factor were analyzed according to the percentage of responses, "Strongly Disagree" (1), "Partly Disagree" (2), "Neither Agree", "Nor disagree" (3) "Mostly Agree" (4) and "Agree" (5). Then, the results were represented in bar graphs (figures) with each affirmative sentence of the questionnaire coded as Q1, Q2, Q3, … Q59.

4.1. Legal requirements

It can be observed in Fig. 2 that the repair stations show commitment to the application of existing regulations (e.g., RBAC 145) (Q1); although, there are occasionally conflicts between these rules (Q2). The conflicts are interesting because RBAC 145 is based on FAR 145 and is very similar to EASA Part 145. Difficulties with the implementation of different systems were also identified by (Gerede, 2015a). Such conflicts were mentioned by more than a half of the repair stations and may hamper the application of the regulation and, therefore, the standardization of work practices. Likewise, it is important to note that repair stations observe different levels of demand between the current regulations, which could lead to underestimation or overestimation of effort and impact cost. This situation likely occurs because maintenance policies applied to aircraft are governed by a mix of airworthiness, authoritative regulations and the choice of suppliers and users (Czepiel, 2003; Regattieri et al., 2015) (Q3, Q4, Q5). It is interesting to note that all repair stations already control their technical manuals, whether completely or partially done (Q3, Q4, and Q5).

Quinlan et al. (2013) argues that foreign Part 145 certified repair stations are subject to a less rigorous inspection regime than domestic repair shops by virtue of the logistical difficulties involved. Furthermore, the Federal Aviation Administration (FAA) has been criticized for its failure to inspect foreign Part 145 certificated repair stations and thereby detect 'significant weaknesses.' This may account for the different degrees of demand between the airworthiness authorities. The fact that some repair shops do not care about the use of maintenance manual copies is worrying.

4.2. Planning and programming

When the aircraft arrives at an airport, the line maintenance process is initiated, including maintenance data acquisition, aircraft status assessment and maintenance decision tasks to be executed (Papakostas et al., 2010). Similarly, repair stations need to plan and program all of the tasks and resources that are necessary for maintenance.

The results of this factor (Fig. 3) show that the planning task is considered relevant to company functioning in attempting to join the routine activities in an organized manner and prepare for unscheduled activities (Q9, Q10, Q11). All repair stations control planning activities using work orders. Gopalakrishnan et al. (2015) says that through strategic planning of maintenance activities, productivity can be increased and maintenance activity planning is an integral decision-making aspect for maintenance engineers. This planning requires support from modern methodologies, data analysis approaches, and information and communication tools (Q12, Q13, and Q14).

Although the use of information systems has recently gained more prominence and widespread use in the industry, including open source software, 7% of repair stations respondents did not have an information system. Still, the majority of aircraft repair stations adopt an information system (Q15) but to a limited extent.

Preparing kits for service order execution facilitates the development of maintenance activities, but there is no consensus among businesses regarding the importance of preparing kits in performing maintenance activities (Q16).

An important issue regarding the planning of activities and consequently the acquisition of parts and performing services is the adaptability of a company in relation to unscheduled activities (Q17, Q18). The occurrence of unscheduled maintenance can introduce costly delays and cancelations if problems cannot be rectified in a timely manner (Papakostas et al., 2010). Selçuk (2013) determined that planners tend to increase/decrease stock levels of spare parts based on information provided on an ad-hoc basis from service engineers or customers. The respondents indicated that repair stations could somehow (fully or partially) adapt to perform these non-schedule activities.

4.3. Information management

According to the answers collected in this factor (Fig. 4), it can be

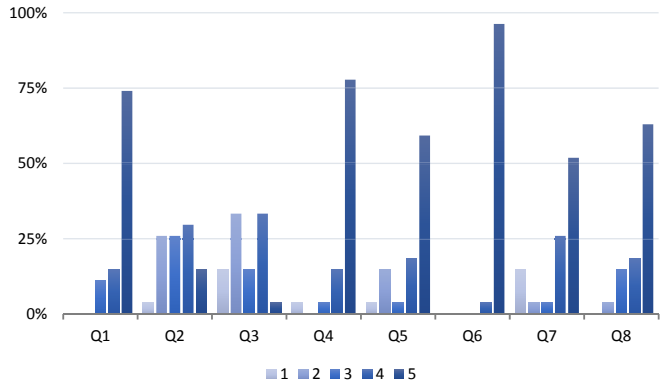

Fig. 2. Percentage of agreement with statements related to "Legal Requirements" factor.

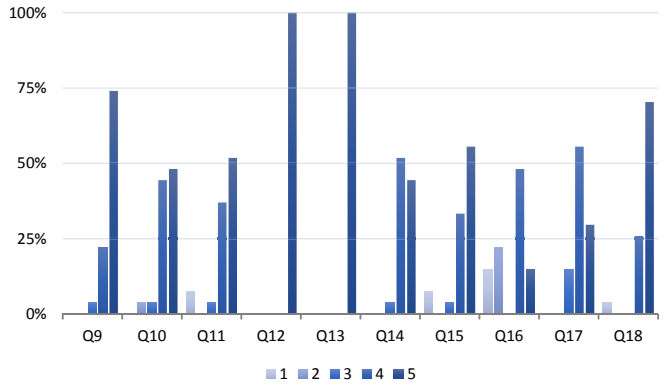

Fig. 3. Percentage of agreement with statements related to the "Planning and Programming" factor.

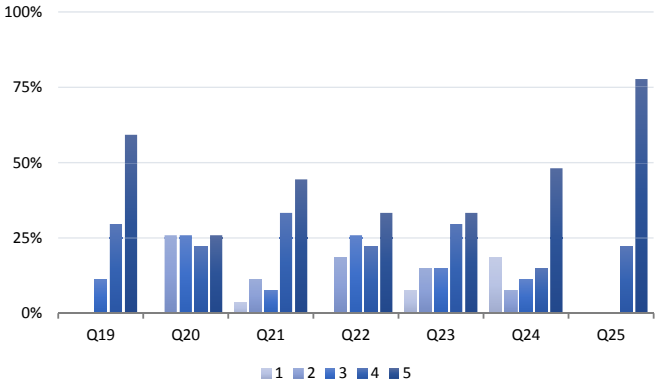

Fig. 4. Percentage of agreement with statements related to the "Information Management" factor.

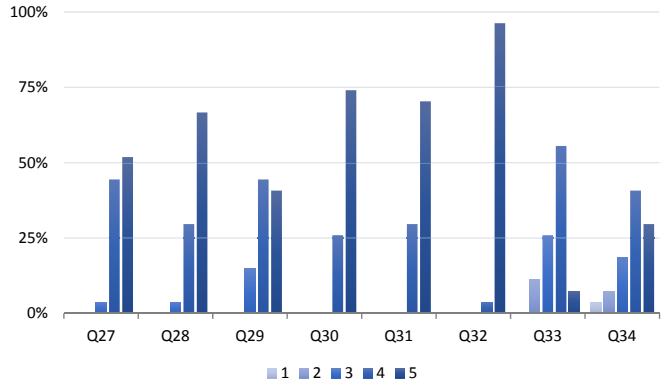

Fig. 5. Percentage of agreement with statements related to the "Resources for Maintenance" factor.

observed that repair stations assign relative significance to information (Q19). It is interesting to note that there is no uniformity in the requirement of proof of language proficiency in written technical orders (TO) in foreign languages. 27% of repair stations report they do not require foreign language proficiency of employees, even if these are involved in activities in which such training is necessary, such as reading TOs, for example. These results are interesting considering an understanding of the English language is essential for the safety of aircraft maintenance operations (Czepiel, 2003; Yadav, 2010). It can be inferred that although there is a necessity to understand manuals by mechanical maintenance staff members, there is no uniform practice regarding the requirement of English as the language to be adopted by technical order users (Q20). A significant portion of repair stations does not have an effective method for controlling suppliers and customers (Q21). Woźny and Blachinio (2015) highlight the control of supplier records as an important tool to achieve consumer needs.

Repair stations reported that 19% maintenance management system users do not receive satisfactory training, 22% reported that the maintenance management software does not meet organizational needs and 26% do not use specific software for the aviation sector in the company management (Q22, Q23, Q24). This fact contradicts the literature, which says that supporting information systems are designed and developed to support and enhance the organizational knowledge creation processes of storage/retrieval, transfer, and application, thus giving organizational members the knowledge they need to make their decisions and perform their tasks. Furthermore, information systems enhance the timeliness and accuracy of the storage and retrieval of information (Abudayyeh et al., 2005; Moreno and Cavazotte, 2015). Q25 shows that information regarding standards and documentation is available for those involved in the maintenance area in 78% of the repair stations interviewed.

These results indicate that repair stations understand the importance of information management but are still far from perfect management.

4.4. Resources for maintenance

In the results of this block of questions (Fig. 5), four issues indicate that the repair stations surveyed showed strong concerns regarding the technical and managerial resources necessary for aircraft maintenance. As observed in Fig. 5, this set of questions has higher compliance response levels among the responding repair stations. A practice adopted by Brazilian repair stations can be considered regarding maintenance features including the following: adequate equipment used by the company, structure defined to support company activities; technical publication business processes; integration between managers and technicians regarding the organizational activities; and equipment calibration (Q27 – Q32).

Notably, specifically with regard to material resources (parts inventory, for example) repair stations, they mostly show partial agreement regarding the availability of these items. In 11% of the cases, spare parts are not available when needed. 12% of the companies do not use inventory turnover control (Q33, Q34). However, spare parts inventories exist to serve the maintenance planning. Because the airline industry involves a large number of parts some of which are quite expensive, it is important to find an appropriate inventory model to achieve the right balance (Gu et al., 2015). Once the control of spare parts progresses through external agents (market availability, for example), it is possible that other factors outside the control of the company may be the cause.

4.5. Support and control

Although repair stations reported that the evaluation of suppliers is important (Q36), 20% of repair stations answered that they do not maintain control over the identification and selection of suppliers in their workshop (Q35) (see Fig. 6). Thus, this identification is not yet a practice adopted unanimously; however, its importance is recognized (Gregson et al., 2015; Ruan et al., 2014; Tretheway and Markhvida, 2014; Woźny and Blachinio, 2015). For 26% of the repair stations, the annual working goals are not shared

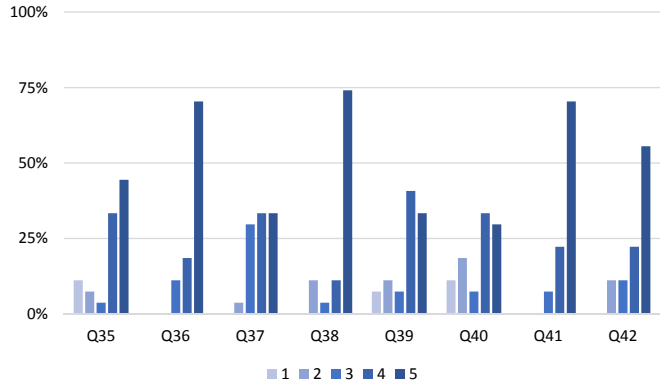

Fig. 6. Percentage of agreement with statements related to the "Support and Control" factor.

with the technicians who perform maintenance activities, which can harm a better understanding of the activities developed by the technicians in relation to the organizational goals.

For inventory management, although inventory control is widely known as a way to manage costs (replacement, storage, order batch, time, etc.) and ensure a competitive advantage for the company, in practice, it is not widely used by the respondent repair stations. In fact, 23% of the stations do not practice inventory control for cost and lead-time for replacement parts (Q37 – Q40). The fact that some repair stations do not use an identification process (segregation) for material whose origin cannot be identified is certainly disturbing (Q41) because one of the most important performance measures is the number of suspected unapproved part(s) infractions (Czepiel, 2003).

4.6. Safety

Fig. 7 shows that repair stations, in most cases, are committed to meet the material and human error security requirements (Q41 – Q44). However, it is observed that in some cases, repair stations report not having absolute control of security items. In Q46, 26% of repair stations report that the inspection stamps do not receive control regarding their use. Likewise, in Q50, 4% of repair stations report no 24-h control of their spare parts stock. Meanwhile, only 4% of repair stations report that the traceability of spare parts still needs process improvement (Q45).

Interestingly, Q42 and Q48 were developed from the listing of the largest non-conformities in relation to RBAC 145, provided by a survey conducted by the Fifth Regional Service of Civil Aviation (SERAC 5) (Machado et al., 2009). However, contradicting that survey, 56% of repair stations reported that maintenance activities are performed and 70% of responding organizations report having their electronics properly stored and packaged. The results of this factor reinforces the findings in the literature that the safety issues in the outsourced repair stations are concerning (Gregson et al., 2015; McDonald et al., 2000; Quinlan et al., 2014, 2013).

4.7. Human resources

An aviation system, including aircraft maintenance, is “a complex system that requires an assessment of the human contribution to safety and an understanding of how human performance may be affected by its multiple and interrelated components” (ICAO, 2013b). The workforce represents a significant portion of the organizational costs (Belien et al., 2012; Tang and Elias, 2012), but in the aeronautical maintenance context, apart from the cost, the workforce has significant importance for ensuring the airworthiness of the fleet (Rankin et al., 2000; Yadav, 2010). Practices of the respondent repair stations comply with safety standards concerning the operator protection (Q51). This is likely due to the imposition of Brazilian labor laws and service of the existing RBAC 145. In 18% of repair stations, there is no program or planning about staff replacement (Q52).

Although repair stations see the training and qualification of their employees as a common practice (48% strongly agreed and 48% somewhat agreed) (Q53) and training planning practice is structured, very few of the stations (4% strongly agreed and 41% somewhat agreed) perform replacement planning for their professionals over time, which shows that businesses are only partly planning their workforce.

The literature shows that identifying the right incentives for the employees has always been an issue in human resource management. However, many organizations are unable to identify the types of rewards that are best used to foster employee job satisfaction (Bustamam et al., 2014; Güngör, 2011; Šajeva, 2014). On the other hand, organizations participating in this study showed no commitment to reward, motivation and employee encouragement (Q54, Q55, Q56). In the samples in this study, a dependence on outsourced services is not observed (Q57). Quinlan et al. (2014) identified significant differences in the proportion of certified workers and training programs, similar to the findings of this research (Q58). The encouragement of technically focusing on airworthiness is a positive point in the surveyed organizations (Q59).

The results presented in Fig. 8 can lead to the conclusion that repair stations use some of motivational programs for their employees, which are mostly developed by the companies themselves. Still, there are no rewards programs for above average employee performance.

5. Conclusions

This study examined the maintenance practices employed by repair stations in the Brazilian aeronautical maintenance industry. It used a qualitative exploratory research approach with questionnaires to verify their compliance with aviation industry maintenance management practices. Therefore, this research presented an overview of the status of management practices in the Brazilian aircraft repair stations, according to established criteria that was developed based on a literature review, regulations and standards. Furthermore, the research analyzed existing practices of repair stations in this sector. The seven factors developed for the assessment of maintenance management practices were suitable to the purpose of the research and allowed for the identification of the

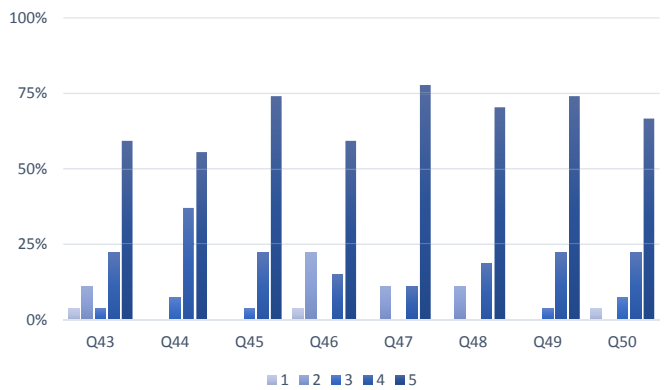

Fig. 7. Percentage of agreement with statements related to “Safety” factor.

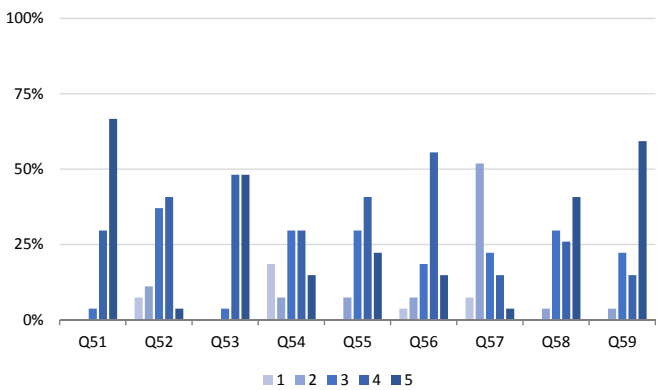

Fig. 8. Percentage of agreement with statements related to “Human Resources” factor.

relevant findings.

When assessing *legal requirements*, it was identified that the gap between requirements in audits from different airworthiness areas are a relevant factor for organizational performance, requiring repair stations to prepare for different types of requirements from several airworthiness authorities. Despite the good preparation of the repair stations in the *programming and planning* of their activities, the use of information systems for this activity is limited. Although organizations attempt to provide all necessary *information* to maintenance technicians and managers, a lack of proficiency in the technical publication language used in the maintenance can lead to unsafe airworthiness situations. It is very important for organizations to ensure the availability of *resources for maintenance*. However, these same organizations fail to replace and control spare parts. This fact can significantly influence maintenance costs. With regard to maintenance *support and control*, the evaluation of suppliers is an important activity for safety. It is evident that Brazilian repair stations fail with regards to this aspect. When assessing *safety*, it was noted that repair stations are aware of the importance of safety to airworthiness; however, this study identified a certain gap between the responses obtained and the reality in reporting by the Fifth Regional Service of Civil Aviation. This research revealed that outsourced organizations have difficulty dealing with *human resources*, except for the personal protective equipment for technicians and the awareness of technicians with regard to continued airworthiness.

The organizations surveyed showed great efforts to be aligned to the best aeronautical maintenance management practices; however, some important points for airworthiness may be being overlooked. In general, all of the assessed factors showed some degree of deficiencies that can affect the costs and quality of maintenance operations as well as the continued airworthiness. Some maintenance management disorganization points are present in the data analysis of the questionnaires, which includes the poor training, planning and supervision. The lack of availability and control of spare parts as well as the lack of an established identification process for segregating materials also indicate poor maintenance management. More specifically, with regard to safety, Brazilian regulations do not have a standard, as recommended in Annex 19 by ICAO (ICAO, 2013a). This lack of regulation may increase the disorganization in the implementation of actions to ensure continued airworthiness.

Because this study uses a qualitative exploratory research technique, it is not possible to generalize these results. However, these results support the hypothesis raised in previous work that outsourcing aircraft maintenance can threaten aircraft airworthiness. The results of this work may also lead to further quantitative studies using correlations between accidents or incidents and outsourced maintenance failures. In addition, comparative studies may be completed on the performance of outsourced aircraft maintenance companies. It is recommend that, in future works, an in-depth case study methodology is used because the problems of maintenance management practices of the companies surveyed can be associated with the inefficient airworthiness audits and factors beyond the control of repair stations.

Appendix 1

Questionnaire

Legal requirements

Q1 The certification is an important tool for quality assurance.

Q2 The requirements of different certifications (ANAC, FAA, EASA) are conflicting.

Q3 Audits from different certifications organisms have the same level of care.

Q4 The authorities have access to the quality system of your business.

Q5 Changes in documentation involve regulatory bodies and are in accordance with regulatory requirements.

Q6 There is control of the Technical Orders (TO), like revisions and updates.

Q7 The practice of holding copies of Component Maintenance Manuals (CMM) is discouraged in the company.

Q8 It is important for my company to obtain additional certifications.

Planning and programming

Q9 The execution of our services is performed based on an established process.

Q10 Activities planning is conducted at least once a year.

Q11 Services planning is conducted by a particular area, responsible for this activity.

Q12 The company uses service orders as a way to control the activities to be performed.

Q13 When using work orders, there is effective control of those already executed.

Q14 Service orders request, planning, and evaluation are effective.

Q15 The company uses an information system for maintenance management.

Q16 There is a kit preparation system for the execution of work orders.

Q17 The company can successfully adapt to situations of non-scheduled activities.

Q18 The quality department works closely with maintenance technicians to improve processes.

Information management

Q19 The company has a system that facilitates communication between the mechanics and managers.

Q20 The company requires proven proficiency from employees whose functions require the use of foreign language.

Q21 The company has a method to control records of suppliers and customers.

Q22 Maintenance IT users receive training that fully meet industry needs.

Q23 The maintenance management software meets the needs of management and controls in your company.

Q24 The maintenance management software is specific to the aviation industry.

Q25 All standards and documentations are available for those involved in maintenance activities.

Resources for maintenance

Q27 The company is properly equipped (tools, workbenches, tests) to offer the intended maintenance services.

Q28 The company intends to expand its qualifications, investing in offering new or improved services.

Q29 The organizational structure is adequate to support activities execution.

Q30 The company has a specific sector to take care of technical publications.

Q31 There is integration between technicians and managers regarding the organization of maintenance activities.

Q32 Instruments and tools used in maintenance are regularly calibrated.

Q33 Replacement parts are available when needed.

Q34 Controls are used for inventory turnover of warehouses.

Support and control

Q35 There is a process of identifying and selecting suppliers.

Q36 Supplier evaluation is very important.

Q37 Inventories quantity and value are controlled.

Q38 There is a written procedure for inspection of incoming spare parts.

Q39 Inventory cost and spare time are monitored.

Q40 Annual maintenance goals are shared with service technicians.

Q41 There is a segregation of material process in the company for parts whose origin cannot be identified.

Q42 The company offers a special environment where they control factors that may influence service compliance.

Safety

Q43 The services, provided by my company, influence flight safety.

Q44 Technicians must be trained on “human error” factors.

Q45 The lack of material identification can compromise traceability.

Q46 Stamps used by the inspectors are controlled and documented.

Q47 I believe there will always be a need for a properly certified mechanic on aircraft repair stations.

Q48 The electronic equipment used by the company is properly stored and packaged.

Q49 Maintenance technicians follow safety policies and procedures.

Q50 There are 24-h a day security and control in the warehouse.

Human resources

Q51 The company complies with safety standards regarding technicians’ protection.

Q52 Technicians’ replacement over the years is expected and planned.

Q53 Technicians assigned to specific tasks are properly trained and qualified.

Q54 There is an employee reward program for above average performance.

Q55 There is an initiative in your company to improve employee satisfaction and welfare.

Q56 The company encourages good ideas suggested by employees.

Q57 The company is highly dependent on the outsourcing of specialized services.

Q58 There is a schedule of training for technicians involved with maintenance.

Q59 Technicians are encouraged to carry out their activities with a focus on continued airworthiness.

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