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**AN OBJECTIVE APPROACH FOR RISK-BASED OVERSIGHT PLANNING**

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## SUMMARY

<b>ABSTRACT.....</b>	<b>5</b>
<b>1. INTRODUCTION .....</b>	<b>6</b>
1.1. <i>Evolution of Risk-Based Oversight in Civil Aviation .....</i>	<i>7</i>
1.2. <i>Risk-Based Oversight concept .....</i>	<i>8</i>
1.3. <i>Risk Based Oversight and ANAC.....</i>	<i>11</i>
<b>2. RELATED WORK .....</b>	<b>13</b>
2.1. <i>Benchmark with other Civil Aviation Authorities (CAA) in RBO introduction - “Practices for Risk-based Oversight” (EASA, 2016).....</i>	<i>13</i>
2.2. <i>“A Quantitative Model for Aviation Safety Risk Assessment” (Shyur, 2008).....</i>	<i>14</i>
2.3. <i>“Risk Assessment Techniques for Civil Aviation Security” (Tamasi and Demichela, 2011):.....</i>	<i>14</i>
2.4. <i>“Multi-Criteria Decision Analysis, Methods and Software” (Ishizaka and Nemery, 2013) .....</i>	<i>15</i>
<b>3. METHODOLOGY .....</b>	<b>16</b>
3.1 <i>Airlines Safety under RBAC n° 121 .....</i>	<i>16</i>
3.2 <i>Training Organizations under RBAC n° 141 .....</i>	<i>19</i>
3.3. <i>Airlines Security under RBAC n° 108 .....</i>	<i>21</i>
<b>4. RESULTS.....</b>	<b>26</b>
4.1. <i>Airlines Safety under RBAC n° 121 .....</i>	<i>26</i>
4.2 <i>Training Organizations under RBAC n° 141 .....</i>	<i>28</i>
4.3. <i>Airlines Security under RBAC n° 108 .....</i>	<i>31</i>
<b>5. CONCLUSION .....</b>	<b>35</b>
<b>REFERENCES .....</b>	<b>36</b>

## LIST OF TABLES

Table 1. Risk profile objective criteria

Table 2. Risk management performance quiz

Table 3. Risk management performance checklist

Table 4. Variables used in the TOPSIS for air operator structure and for quality control data.

Table 5. Indicators of the first stage of CATO RBO planning methodology.

Table 6. Indicators of the second stage of CATO RBO planning methodology.

## LIST OF FIGURES

Figure 1. Risk-Based Surveillance concept

Figure 2. Aviation growth and oversight resources required, with and without RBO, to keep the number of accidents reducing

Figure 3. PDCA process for RBO

Figure 4. Sample Dispersion Graph

Figure 5. National Airlines Dispersion Graph

Figure 6. Foreign Airlines Dispersion Graph

## **ABSTRACT**

This work aims to propose methodologies to be applied for ANAC oversight planning process. The goal is to develop a more efficient risk-oriented framework to determine a risk profile through objective indicators that will point into areas and operators that should be receiving more surveillance. The expectation is that the developed methodologies will contribute to support Risk-Based Oversight implementation at ANAC and a more efficient way of allocating government resources while risk will be properly addressed, adding a more intelligent planning process based on analytical but objective criteria to manage surveillance, prioritizing and tailoring oversight activities based on individual service provider risk profile.

## 1. INTRODUCTION

Recently, Brazilian Civil Aviation Agency (ANAC - *Agência Nacional de Aviação Civil*) has chosen as a top priority the implementation of the State Safety Programme (PSOE-ANAC). Sponsored by the board of Directors, priority projects have been established in 2017, to study and structure ways to implement the PSOE-ANAC in all departments of the Agency, including one project focused on risk management and its application in continued oversight actions. Similarly, ANAC established in its internal Security Program (PAVSEC-ANAC) the need to carry out surveillance planning based on risk management.

In the wake of what has been developed by PSOE-ANAC priority projects and by security-related initiatives derived from PAVSEC-ANAC, this work aims to propose methodologies to be applied in ANAC's oversight planning process, for both safety and security aspects. These methodologies have been developed and tested to distinct sets of regulated organizations, in order to verify its comprehensiveness in different aviation sectors, where variables like the service provided, the number of certified operators, the level of safety/security required, the number of people exposed to the operational risk, among others, differ.

The goal is to develop a more efficient risk-oriented framework to determine a risk profile through objective indicators that will point into topics and operators that should be receiving more surveillance. The expectation is that the methodology developed will contribute to support Risk-Based Oversight (RBO) implementation in ANAC and, in addition, will optimize the government resources allocation. Human and financial resources are limited and tend to be increasingly scarce with the growth of the air sector.

Aiming to optimize ANAC's resources and properly address oversight needs, three applications of the RBO planning methodology are proposed here. The first one is tailored to airlines operating under RBAC nº 121<sup>1</sup> (safety aspects); the second one, to training organizations operating under RBAC nº 141<sup>2</sup> (safety aspects); and the last one, to airlines

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<sup>1</sup> RBAC nº 121, or *Regulamento Brasileiro da Aviação Civil* (Brazilian Civil Aviation Regulation) nº 121, is the Brazilian rule on Public air transport operations with airplanes with a maximum certified passenger seat configuration of over 19 seats or a maximum payload capacity of over 3,400 kg.

<sup>2</sup> RBAC nº 141, or *Regulamento Brasileiro da Aviação Civil* (Brazilian Civil Aviation Regulation) nº 141, is the Brazilian rule on Certification and Operational Requirements for Civil Aviation Training Organizations.

operating under RBAC n° 108<sup>3</sup> (security aspects). As showed in the following section, academic references on the subject, in general, approach it conceptually and philosophically, and the application examples are aimed at airlines under RBAC n° 121 in safety aspects. Thus, the methodology proposed here for airlines under RBAC n° 121 was based on the experiences reported, with the necessary adaptations to the Brazilian case. For the other segments, training organizations and airline security aspects, the methodologies are innovative, although built on the same RBO philosophy, considering the characteristics and set of data and information available about those regulated companies.

### **1.1. Evolution of Risk-Based Oversight in Civil Aviation**

Developing an RBO approach is a challenge that has been faced by many Civil Aviation Agencies (CAA) around the world. Since the publication of Doc 9859 (ICAO, 2018) in 2006 and ICAO Annex 19 (ICAO, 2016) in 2013, the concepts of Safety Management System (SMS) and State Safety Program (SSP) were introduced and the development of the SMS by the civil aviation service providers, with guidance and support from the CAAs, evolved significantly. The central point is risk management, as it is not enough for a service provider to just comply with regulatory requirements. It must be able to identify and manage the safety risks related to its operation in order to achieve and maintain the operation and the aviation system safe.

The mindset shift in aviation from “compliance” to “risk management associated with compliance” has led the States to develop strategies, methodologies and tools to implement a risk-based or performance-based oversight.

According to the UK CAA (2018), “a change to RBS<sup>4</sup> is a very substantial change in everything a regulator does. The focus is more on having challenging risk conversations with industry rather than pure compliance checks. A successful transition to Risk-Based Surveillance will require both the industry and the regulator to adapt to new challenges and be novel and collaborative in their joint approach to safety management. The regulator needs to learn to adopt a collaborative approach and enable itself to listen to industry, and jointly

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<sup>3</sup> RBAC n° 108, or *Regulamento Brasileiro da Aviação Civil* (Brazilian Civil Aviation Regulation) n° 108, is the Brazilian rule on Aviation Security – Airline

<sup>4</sup> The acronym RBS stands for Risk-Based Surveillance.

consider options – it is only then that a true collaborative approach can be established with benefits that will create a new level of transparency between the regulator and industry, benefiting all aviation participants to increase safety. This transparency results in higher levels of trust, without breaking down the clear line that exists between the regulator and its regulated industry.”

## 1.2. Risk-Based Oversight concept

ICAO Annex 19 SSP framework requires “Safety-data-driven targeting of oversight in areas of greater concern or need”. EASA (2016) highlights that “States should establish procedures to prioritize inspections, audits and surveys towards those areas of greater safety concern or need, as identified by the analysis of data on hazards, their consequences on operations, and the associated safety risks.”

RBO allows the CAA to focus resources on organizations and targets that require higher attention, strengthening the efficiency of the oversight and improving the understanding of the risks across the aviation system, which will enable better calibration of the surveillance, as shown in the figure 1. At organizational level, RBO relies on the assessment of the effectiveness and the maturity of the organization’s safety management systems.

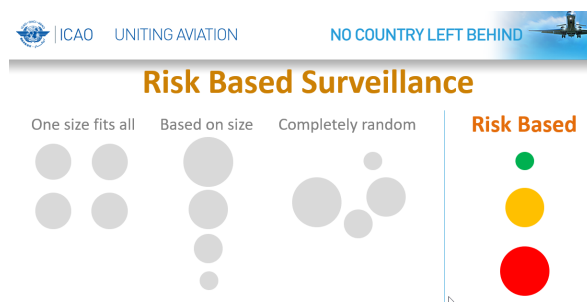


Figure 1. Risk-Based Surveillance concept

Source: SRVSOP (2001).

Risk-Based Oversight is not only about efficiency in safety management but also an opportunity to match steady government human and finance resources with air transport traffic expected growth. In other words, to make more with less, while keeping the required level in operations. As aviation is growing, traditional oversight would request a similar increase of resources. RBO provides more flexibility to the regulator to better allocate its staff by driving

more intensive oversight for companies having a high-risk profile. Thus, with the implementation of RBO, risk will be properly addressed, adding a more intelligent planning process based on analytical but objective criteria to manage surveillance, prioritizing and tailoring oversight activities based on individual service provider risk profile, which represents oversight effectiveness increase, together with resources allocation efficiency increase.

Figure 2 shows that RBO is an important tool to address the need to maintain current aviation safety statistics even with expected air traffic growth, through a more efficient allocation of limited government resources, allowing aviation safety management less dependent of CAAs' budget constraints.

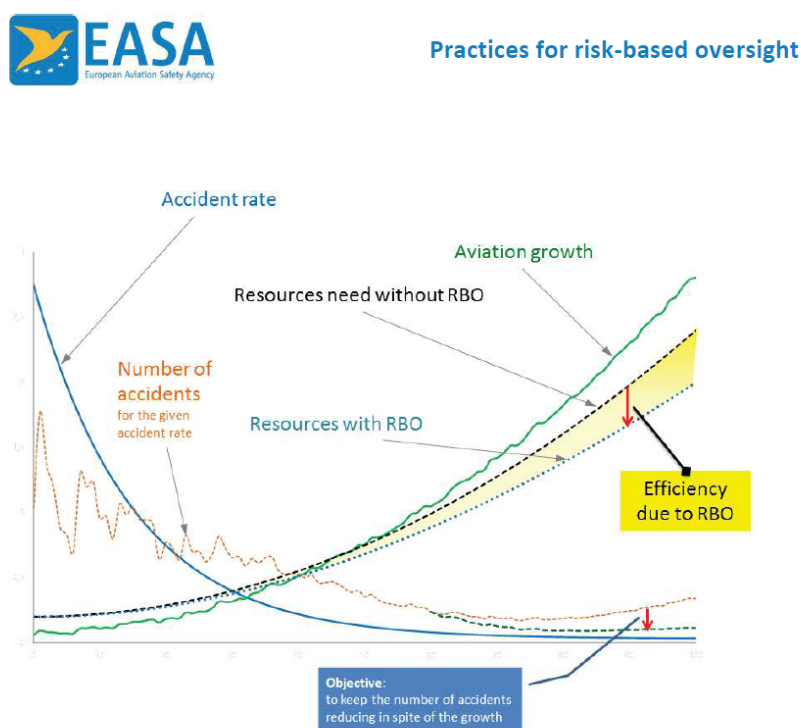


Figure 2. Aviation growth and oversight resources required, with and without RBO, to keep the number of accidents reducing.

Source: *Practices for Risk-Based Oversight* (EASA, 2016)

RBO can be understood as a framework to carry out surveillance, where planning is guided by the combination of "risk profile" and "safety performance" and execution focuses on risk management, in addition to ensuring compliance.

Risk profile is determined by the risk elements that are inherent to the nature and operations of the regulated including, but not limited to:

- the specific nature of the organization;
- the complexity of their activities;
- the risks inherent in the activities carried out;
- the degree of innovation or prior application of an activity in the regulated entity.

Safety performance is continuously changing over time, as it is the direct outcome of the continued operations of the regulated entity and can be defined as the demonstration of how effectively a regulated entity can mitigate its risks through the:

- compliance with the applicable requirements;
- effective safety risks identification, control and management;
- achievement and support of continuous safe operations;
- efficient systemic measures to correct past certification and/or oversight's findings.

Performance-based oversight (PBO) measures the health of the system under scrutiny and ultimately assessing its overall performance, through specific that either identifies risks within that system or measures safety risks and monitor measures to mitigate these risks. PBO meets RBO when the PBO comes to support the identification of areas of greater risks to facilitate the risk assessment and mitigation process.

Key benefits of Risk-Based Oversight are:

- Improved safety performance
- Value-added risk identification
- Proportionate levels of oversight
- Improve relationship with industry by a two-way process
- Improved resource to risk management
- Collaborative assessments and information sharing

Risk-Based Oversight core principals are:

- Proportionate: planning of the required surveillance level is based on individual risk and performance;
- Targeted: identifying the key areas for concern based on focused consistent risk analysis;

- Efficient: assigning resource to issues requiring the most attention in the most efficient way possible;
- Flexible: responsive to incidents and adjustable to adapt when issues arise.

RBO can be also understood as PDCA process (Plan, Do, Check and Act) and feedback loops as described in figure 3:



Figure 3. PDCA process for RBO

Source: *Practices for Risk-Based Oversight* (EASA, 2016)

### 1.3. Risk Based Oversight and ANAC

ANAC has formally determined that RBO is a top priority project at State level as a tool for Brazilian civil aviation system risk management. This chapter will present policies established by ANAC for RBO, through the State Safety Programme (PSOE-ANAC) and Security Programme (PAVSEC-ANAC).

According to ANAC (2018), surveillance activities planning and execution based on risk profile groups and safety/security performance of each organization or individual, should determine the duration of the surveillance cycle, the interval between activities and the prioritization of aspects to be verified, making the oversight more effective.

RBO planning and execution is a complex process and should consider information obtained by previous surveillance activities (audits and inspections), operational safety/security events, changes in management processes and positions, efficiency and effectiveness in the correction of findings, maturity of the Safety Management System (the Security Management System, although predicted, is not a requirement), attitude of the regulated with the regulator, among other indicators of safety and security performance.

The first step towards RBO is the classification of individuals in a risk profile, which will further allow the targeting and the prioritization of surveillance activities (inspections, audits, etc.) planning. The size, scope, and complexity of operations, including risk exposure should be considered. Thus, the standard duration of the inspection cycle will be a function of the risk profile of each individual after objective data combined with expert's judgment to define risk profile.

To ensure a consistent risk profile definition, an objective model and the specialists judgment should be considered. Decision-making process is recommended to be consensus among subject matter experts to support a continuous individual risk profile reassessment.

When an objective model or scoring system for risk profile is used, some aspects should be considered as described below:

- Need to review parameters over time, according to aviation evolution and adherence to current reality;
- Calibration and weighting of parameters, avoiding distortions caused by the weight of a single factor;
- The relevance and consistency of the result, rather than focusing solely on scoring system modeling;
- The significance of parameter variation, rather than absolute results;
- Outliers investigation to avoid inconsistent risk profile classifications.

It is important for RBO planning not to be a rigid process, but otherwise an initial expectation of resource allocation. The driver for planning should always be the perceived risk, which is often dynamic.

## 2. RELATED WORK

Shyur (2008) states that “in order to ensure the public safety and maintain safe aviation environment, developing an analytic method that moves beyond the essential identification of risk factors to assess the safety performance and discover the potential hazards of airlines is indispensable.” His research developed an application of the hazard regression models to the analyses of aviation risks that had not been previously reported in the literature, proposing a new quantitative methodology for the assessment of risk in civil aviation through a spline function used to present the baseline hazard function. His modified proportional hazards model takes into account the relationships among relevant aviation risk factors and allows the dependence of aviation risk and operational performance of airlines to be measured.

However, there is a lack of research to investigate how to manage risk in air transport industry, notably in a more proactive way of avoiding potential risks through independent and intelligent oversight capable to find soft spots that should be addressed before a trend develops. Previous studies are more focused on how to assess accidents, incidents and occurrences statistics to find trends and gaps to be addressed in the system.

What we are looking here is to develop an initial and object methodology customized to Brazilian context to be improved later, that aims to understand regulated service providers risk-based on more comprehensive analysis robust enough to avoid mitigate and control present risks before undesirable results become true. The system under ANAC responsibility to accomplish that is being discussed in this study is the oversight activities’ results assessment through a SMS (Safety Management System) approach. To support that discussion and considering that only after 2016 regulators have started releasing policies for RBO, our research and methodologies development has focused on other authorities benchmarking.

### **2.1. Benchmark with other Civil Aviation Authorities (CAA) in RBO introduction - “Practices for Risk-based Oversight” (EASA, 2016)**

The objective of these guidelines is to provide a common understanding of RBO criteria and processes in order to help National Supervisory Authorities (NSAs) to adopt a Risk Based Oversight approach when conducting their oversight tasks.

RBO implementation successful stories from Swiss, British, Irish and Swedish's Civil Aviation Authorities (CAA) and risk profiling methodology from Irish, Spanish, Swiss and Finish's CAAs have been investigated as case studies to benchmark and customize best practices from worldwide recognized authorities to ANAC regulated environment. More relevant criteria common to most of analyzed cases have been incorporated to the purposed methodology.

## **2.2. "A Quantitative Model for Aviation Safety Risk Assessment" (Shyur, 2008)**

This research developed a quantitative methodology for the assessment of risk in civil aviation that uses accident and safety indicators to quantify the aviation risks which are caused by human errors. Focused on air carrier operations and performance, the author uses data and indicators from the Fight Safety Management Information System developed by the office of the Taiwan Civil Aeronautics Administration, together with a sample of 61 major accident records in a two-year period, to assess the probability of occurrence of a specific type of human error aviation accident. The proposed analytical model considers many varied, yet interrelated human, technical, environmental and organizational factors that affect safety and system performance. Shyur (2008) concludes that "the results demonstrate that the proposed model is a more promising approach with the potential of becoming very useful in practice and leading to further generalization of aviation risk analysis."

Results presented by Shyur (2008) could be considered in future improvements to the methodologies proposed here. It would demand oversight data (obtained from air carrier, aircraft, crew, ground personnel, maintenance and operation performance inspections and audits) integration and assessment, besides accidents and incidents records structuring. Despite the difficulties of such a challenge, it is extremely important that the regulator collects and assesses data in a way to understand regulated service providers hazards and risks in a more comprehensive analysis.

## **2.3. "Risk Assessment Techniques for Civil Aviation Security" (Tamasi and Demichela, 2011):**

This paper proposes a set of methodologies aimed at risk assessment processes, quantitative and qualitative, in aviation security, based on the concepts of threat, vulnerability

and criticality associated with the definition of the risk level, considering the economic efforts to establish guidelines for a security management system aimed at improving and adapting aviation security through the identification of risks and control measures, carried out after the 9/11 terrorists' attacks.

The research also emphasizes that the establishment of risk assessment techniques is fundamental for the process of risk identification and assessment in the context of aviation security, since an incorrect identification and quantification of risks in security can considerably affect the level of security applied to protect aviation operations and the investments needed to achieve it. In this sense, although the methodologies proposed in this study are aimed in practice for aerodrome operators, the consideration of the concepts discussed in the scope of aviation security are important for the definition of a methodology that can be adopted by ANAC in its regulatory environment.

#### **2.4. "Multi-Criteria Decision Analysis, Methods and Software" (Ishizaka and Nemery, 2013)**

This book presents an introduction to multi-criteria decision analysis (MCDA) and chapters about each of the leading methods used in this field, as well the comparison of methods and software to enable readers to choose the most appropriate method needed in the research.

Through the evaluation of MCDA methodologies, as well as their step-by-step implementation, presented in this book, it was possible to establish the method called "Technique of Order Preference Similarity to the Ideal Solution", or TOPSIS, for application in risk assessment in the scope of aviation security (AVSEC) aimed to airlines operators, presented below in chapter 3.3.

### 3. METHODOLOGY

The methodologies proposed in this work are based on the principles exposed above, in particular on the concepts introduced in ANAC (2018). Thus, the application of the guidance given in the aforementioned document regarding the risk-based oversight planning was explored here to different sets of regulated companies, namely: airlines safety under RBAC n° 121, training organizations under RBAC n° 141 and airlines security under RBAC 108.

A regulated company has its own risk profile, by nature, which derives from the specificity of its operations. Therefore, each set of regulated entities has characteristics and sets of variables that require the methodology to be tailored considering, among others, the number of certified companies, the service provided (air transport, pilot training, airport operation etc), the level of safety/security required for each segment, the number of people exposed to the operational risk, in addition to the quantity and quality of data and information that ANAC currently has about that segment.

The methodologies presented here were developed and improved with the contribution and evaluation of people working in the technical areas of ANAC responsible for the certification and surveillance of the related regulated sector.

#### 3.1 Airlines Safety under RBAC n° 121

For RBAC 121 operators (airlines), three different steps are followed for oversight activities as described below:

First round for surveillance activities will be planned exclusively considering a proportional sample for each operator's size (fleet, aircraft models, number of technical crew, number of destinations, etc.) and complexity (certified special operations).

Further, the second step is to go deeper on risk profile definition, adding an objective methodology to incorporate qualitative criteria that will be presented below and is one of the objectives of this study.

The final step will be to improve individual risk profile outcome to consider the operator's performance in controlling specific operations risks over the next cycle and update yearly planning for each quarter.

Three different developed tools will be proposed and presented below to objectively qualify individual risk profile and risk management performance for each operator:

a) Objective criteria to determine an operator risk profile:

OPERATOR	A	B	C	D	E	F	G	H	I	J	K
FINANCIAL HEALTH DEGRADATION	1	0	0	1	0	0	0	0	0	1	0
SIGNIFICANT EXPANSION OR RETRACTION (fleet size in operation)	0	0	0	0	0	0	0	0	0	0	0
SIGNIFICANT ORGANIZATIONAL MODIFICATION (M&A, corporate control change, etc.)	0	0	0	0	1	0	0	0	0	0	0
CHANGE OF MORE THAN 2 APPROVED MANAGEMENT MEMBERS	1	0	0	1	0	0	1	0	1	1	1
IOSA CERTIFICATION	0	0	0	1	0	1	0	0	1	0	1
SGSO PERFORMANCE: 1 - (SMS index)	0,17	0,25	0,25	0,59	0,39	0,5	0,18	0,1	0,31	0,11	0,38
RECENTLY CERTIFIED OPERATOR	0	0	0	1	0	0	0	0	0	0	0
<b>AVERAGE=&gt;</b>	<b>0,31</b>	<b>0,035714286</b>	<b>0,035714</b>	<b>0,655714</b>	<b>0,198571</b>	<b>0,214286</b>	<b>0,168571</b>	<b>0,01428571</b>	<b>0,33</b>	<b>0,301429</b>	<b>0,34</b>

Table 1. Risk profile objective criteria

Each criterion will be graded as [1], in case of presence of the determined risk, and [0] in case of absence, as described below:

- Financial degradation: presence of evidence that the company is struggling in keeping its financial obligation, such as payments (leasing, airport fees, fuel, training providers, etc.).
- Expansion retraction considered as significant if more than 20% change in aircraft fleet.
- Organizational modification considered as significant if presence of events such as merge and acquisition, change in the control of the organization, main base operation change, etc.
- Change in top management members that must be approved by the aviation authority: presence of more than 2 members replacement in 1-year interval.
- IOSA certification: presence in case the operator shares all relevant results from recent International Air Transport Association (IATA) Operational Safety Audit (IOSA) certification.
- SGSO Performance Index: only criteria to be graded as a score from [0] to [1]. “*Sistema de Gerenciamento de Segurança Operacional*” (SGSO) is the equivalent to Safety Management System (SMS) for ANAC regulations.
- Recently Certified Operator: if operator initially certified for less than 1 year.

- b) Quiz to objectively qualify an operator risk management performance by safety experts from the authority, considering three main fields described below:
  - i. Transparency on the relationship with regulator authority;
  - ii. Certification performance;
  - iii. Performance in correcting issues resulted from oversight activities.

		QUIZ: experts judgment	OPERATOR	
		CRITERIA		
Management	GCTA	Transparency on the relationship with regulator authority		
		Performance in correcting issues resulted from oversight activities		
		Past certification performance		
	GTCT	Transparency on the relationship with regulator authority		
		Past certification performance		
	COGR	Transparency on the relationship with regulator authority		
		Performance in correcting issues resulted from oversight activities		
	ASCT	Transparency on the relationship with regulator authority		
		Past certification performance		
	ASGR	Transparency on the relationship with regulator authority		
Performance in correcting issues resulted from oversight activities				
POI	PI S.1	Transparency on the relationship with regulator authority		
		Performance in correcting issues resulted from oversight activities		
	PI S.2	Transparency on the relationship with regulator authority		
		Performance in correcting issues resulted from oversight activities		
	PI S.3	Transparency on the relationship with regulator authority		
		Performance in correcting issues resulted from oversight activities		
	PI S.5	Transparency on the relationship with regulator authority		
		Performance in correcting issues resulted from oversight activities		
	PI S.6	Transparency on the relationship with regulator authority		
		Performance in correcting issues resulted from oversight activities		
Transparency on the relationship with regulator authority				
Focal	Past certification performance			
	AVERAGE Performance in correcting issues resulted from oversight activities	#DIV/0!	#DIV/0!	
	AVERAGE Past certification performance	#DIV/0!	#DIV/0!	
	AVERAGE Transparency on the relationship with regulator authority	#DIV/0!	#DIV/0!	
	FINAL AVERAGE	#DIV/0!	#DIV/0!	

Table 2. Risk management performance quiz

- c) Job Aid to support tactical subjective planning based on perceived operator performance by the experts:

SMS Performance Criteria Checklist for RBO Planning:	
	Areas with frequent findings
	Performance to implement corrective measures
	SMS maturity level indicator
	Areas with high risk safety reports
	Safety events (minor occurrences, incidents, accidents)
	Significant change in safety related operational procedures and training
	Change in outsourced service providers for critical areas
	Accountable and safety managers' performance
	Performance of Fatigue Risk Management for safety sensitive area staff

Table 3. Risk management performance checklist

Final results will be computed, and the outcome will be a factor that will be used to adjust surveillance activates sample initially planned for each operator as previously described.

### 3.2 Training Organizations under RBAC n° 141

The oversight annual planning of the set of regulated companies certified under RBAC n° 141, that is, the Civil Aviation Training Organizations (CATO) focused on the training and qualification of pilots, flight attendants, flight mechanics, operational flight dispatchers and aircraft maintenance mechanics presents some differences in relation to the other segments covered in this work, given the particularities of each group.

The number of certified CATOs is considerably higher than that of companies governed by RBAC n° 121 and RBAC n° 108, for example, which makes it difficult to carry out such a detailed analysis proposed for the oversight planning of that segment. In this way, the risk-based oversight planning methodology applied to the CATOs follows the same logic for defining a risk profile, but using different indicators. The methodology for CATOs RBO planning were developed and applied within the Branch of Training Organizations – GTOF/SPL with the assistance of the Advisory Branch – GTAS/SPL of the Department of Civil Aviation Personnel – SPL/ANAC.

The first stage of the planning methodology is to classify the CATOs by the type of training offered. The CATOs that offer only theoretical courses – and there may also be practical courses that do not involve flight training in aircraft – have a different complexity from the CATOs that offer flight training in aircraft, with or without the offer of theoretical courses. They are then classified as CATO type 1 (without practical flight training) and CATO type 2 (with practical flight training). Among CATOs type 2, there may still be classification regarding the size of the fleet and aircraft models used in the training, but at the moment no gain was seen in this differentiation.

The first sample of CATOs to be surveilled in the following year is taken from the simple definition of the frequency in which a CATO type 1 or 2 must be audited or inspected by the regulator. This is the rule used historically in the sector, and the duration of the inspection cycle of CATO type 2 is shorter than that of CATO type 1. The type of surveillance to be carried out on the regulated companies listed in the plan only for the time they have not being visited is more comprehensive and does not go deep into specific topics, focusing on verifying the maintenance of the certification requirements.

The second stage of planning is to improve the risk profile by observing some performance indicators related to characteristics or results of courses offered by CATOs. It is important to highlight that the set of indicators used must reflect the perceived risk of the

segment at that moment. Also, it may be a limitation of indicators due to the lack of data available. In the exercise carried out in 2021 for the 2022 oversight planning, the following indicators have been used:

- Success in the theoretical exam applied by ANAC: after taking the theoretical course, the students must submit to the theoretical exam applied by the regulator to then proceed with their flight training and practical exam. The indicator of success in the theoretical exam of students from each CATO helps to direct the surveillance effort towards theoretical courses that potentially have below-average quality, given the performance of the students;
- Number of students graduated in flight courses for private pilot of airplane and helicopter: the greater the volume of students trained in practical courses, specifically in basic training, the greater the potential risk for the system, which is why greater attention should be paid to the CATOs type 2 who graduate greater number of pilots in flight courses;
- Number of hours of flight training for private pilots of airplane and helicopter: CATOs type 2 that graduate, on average, private pilots with fewer flight hours will be prioritized over those that graduate with more flight hours, since the probability of the student having acquired all required skills increase with the number of hours of flight training;
- Occurrences of accidents and incidents: the recent history of occurrences compiled by the body responsible for investigating accidents and incidents, CENIPA<sup>5</sup>, will lead to prioritization of the involved CATOs in the annual inspection.

The second sample of CATOs to make up the oversight plan for the following year is obtained by defining values from which the above indicators lead to the eligibility of surveillance of a CATO. The regulator's ability to execute the plan is also observed in this definition, depending on available resources. The types of surveillance vary depending on the reason (indicator) that led the CATO to be listed in the sample, where specific topics will be further explored during the inspection. Some CATOs in this second sample are eligible due to more than one indicator, in addition to eventually coinciding with those CATOs obtained by the inspection cycle (sample of the first stage).

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<sup>5</sup> CENIPA – *Centro de Investigação e Prevenção de Acidentes Aeronáuticos* (Aeronautical Accident Investigation and Prevention Center) is the body of the Ministry of Defense responsible for the investigation of aeronautical accidents in civil aviation and the Brazilian Air Force.

A third, subjective stage is carried out by the department managers, consulting the staff team who deal with CATOs certification and surveillance on a daily basis. They analyze the adequacy and reasonableness of maintaining the CATOs obtained in the first two stages of the inspection planning and will make any adjustments they deem necessary, including the possibility of adding new CATOs to the list. The history of previous inspections and audits, any pending issues, not investigated denunciations and the behavior of the regulated company vis-à-vis the regulator are reasons that could give rise to new inclusions in the plan. At that time, the adjustment is also made regarding the type of surveillance to which each CATO must be submitted.

At last, a reserve of surveillance actions – or, better said, a reserve of resources – is made for the needs that arise throughout the year. As an example, there are denunciations to CATOs that demand immediate oversight action by the regulator; occurrence of events such as accidents or incidents that also require immediate action; relevant change requested by the CATO, such as the reformulation of an instructional program; among other possibilities.

### **3.3. Airlines Security under RBAC n° 108**

In aviation security (AVSEC) aspects, the risk management associated with airlines must take into account variables from different information sources. According to Tamasi and Demichela (2011), the quantitative risk assessment can be subdivided into the following steps:

- Threat assessment
  - o Detection of the presence of hostile groups
  - o Evaluation of the threat level in the nation
  - o Evaluation of the threat level near the operation airports
- Vulnerability assessment
  - o Analysis of the critical points and the functional importance of systems and infrastructures
  - o Evaluation, within the system of aviation security, of protection systems for every critical infrastructure and evaluation of the accessibility and vulnerability levels
- Criticality assessment
  - o Analysis of the potential accidental scenarios consequent to the success of the attacks on critical targets

- o Analysis of the costs for the re-establishment of the critical targets and evaluation of the missed indirect incomes because of their unavailability
- o Evaluation of the economics losses related to every accidental scenario

Thus, the quantification can be reach by the following relation:

$$\text{Risk} = (\text{Threat} \times \text{Vulnerability}) \times \text{Criticality}$$

In Brazil, according to Decree No. 7,168, which consists of the National Security Program (PNAVSEC), the threat assessment comes from the Federal Police Department (DPF), an agency designated as the primary public security force at public airports, through intelligence information, and the assessment of vulnerability are provided by ANAC through inspection activities and AVSEC Quality Control. The criticality assessment, as set out in the research by Tamasi and Demichela (2011), comes from airport operators through specific operational information from the airport, and is not part of the scope of the risk assessment developed by ANAC as an authority and considering the national scope.

Considering that different information sources consist of non-standardized data, in the case DPF and ANAC with different activities, to extract an analysis for the risk profile in AVSEC of airlines, an analysis using a Multi-Criteria Decision Analysis (MCDA) method is necessary. These methods are defined by a set of decision support methods in which several criteria are used iteratively, providing springboards and techniques for finding a compromise solution.

Many methods have been developed to solve problems with various criteria. Since the objective of this study is to define the air operators with the highest AVSEC risk and thus prioritize activities and mitigation measures in these operators, the method called TOPSIS, stands for Technique of Order Preference Similarity to the Ideal Solution, was the option to be used. This technique requires a minimal number of entries, and the fundamental idea is that the best solution is the one with the smallest distance from the ideal solution and the greatest distance from the anti-ideal solution. The solution is based on a list of priorities based on the level of risk, where rank one is considered the air operator with the highest risk. This methodology is also suitable for modeling quantitative problems, as it requires less subjectivity, which makes the data collection process simpler.

The calculations were generated in *Microsoft Excel* by an expert in statistics at ANAC, following the step-by-step present in the Multi-Criteria Decision Analysis, Methods and

Software (Ishizaka and Nemery, 2013). The six steps to achieve the classification planned for TOPSIS was adapted to facilitate the results for the AVSEC risk assessment for air operators, from normalizing the values of the variables to the final classification, as below:

1. Normalize values
2. Find positive ideal solution
3. Find negative ideal solution
4. Calculating the distances for an ideal point and a non-ideal point
5. Set distance of each air operator
6. Ranking

For the development of the TOPSIS methodology applied to the air operators AVSEC risk assessment, the following variables were considered:

- Air operator structure: quantitative data that includes the total domestic and/or international passengers transported, the total domestic and/or international air cargo transported and the number of airports where the airline operates;
- Threat level: three criteria used by the Federal Police (threat assessment questionnaire, analysis by organized group profile and by specific information about probable real or imminent threats to the analyzed system); and
- Vulnerability level: ANAC bases the definition of the vulnerability index of air operators based on data extracted from two AVSEC quality control processes:
  - o inspection (audits and inspections), considering the proportion of regulatory requirements assessed as non-conforming (or irregular), for each air operator at each airport base, as well as the weight (severity) of non-compliance with each requirement and the resulting period for the adoption of actions corrective or mitigating; and
  - o occurrence reports in AVSEC, considering the index of severity of the triggering event of the report and the rate of voluntary reports (not delations).

The proposed AVSEC risk assessment for air operators begins with an analysis based on the steps of the TOPSIS methodology, considering the variables defined for the air operator structure, containing passenger and cargo movement combined with the threat level provided by the Federal Police. Then, another analysis is also carried out using the steps of the TOPSIS methodology, considering the variables defined for the Quality Control Data, containing information from the results of AVSEC audits and inspections combined with information from

reports of occurrences in AVSEC. In Table 4, all the variables used in TOPSIS methodology are presented segregated by “Air Operator Structure” and “Quality Control Data”.

AIR OPERATOR STRUCTURE	QUALITY CONTROL DATA
<ul style="list-style-type: none"> <li>• Total Domestic Passengers</li> <li>• Total Domestic Cargo</li> <li>• Total International Passengers</li> <li>• Total International Cargo</li> <li>• Verified Threat Level</li> </ul>	<ul style="list-style-type: none"> <li>• Ponder Vulnerability in Audits and Inspections</li> <li>• Proportion of Non-Inspected Bases</li> <li>• Corrective Actions Progress</li> <li>• Reporting Severity Index</li> <li>• Reporting Voluntary Index</li> </ul>

Table 4. Variables used in the TOPSIS for air operator structure and for quality control data.

After performing the steps of TOPSIS for Air Operator Structure and for Quality Control Data, the results are united in a Dispersion Graph, taking care to normalize the information by the average so that the comparison of the two parts is feasible. With this normalization, air operators would be grouped into 4 (four) quadrants defined by the average, presenting as separation axes "x" for Air Operator Structure and "y" for Quality Control Data), as shown in Figure 4.

The first step to prepare the Dispersion Graph is to create a database with the final result of the TOPSIS calculation referring to the Air Operator Structure and Quality Control Data of the analyzed air operators. Then, these results must be normalized by the average so that the comparison of the two parts is feasible, making the average of the normalized values equal to 1. With this normalization, the air operators would be grouped into four quadrants defined by the average, having as axes of separation ( $x=1$ ,  $y=1$ ), as shown in Figure 4 where each point represents an analyzed air operator. The condition for an operator to belong to a certain quadrant is listed below:

- **High AVSEC Risk (red):** High “Structure of the Air Operator” and High Irregularity in “Quality Control Data”;
- **Medium-High AVSEC Risk (orange):** Low “Air Operator Structure” and High Irregularity in “Quality Control Data”;
- **Medium-Low AVSEC Risk (yellow):** High “Air Operator Structure” and Low Irregularity in “Quality Control Data”;
- **Low AVSEC Risk (green):** Low “Air Operator Structure” and Low Irregularity in “Quality Control Data”.

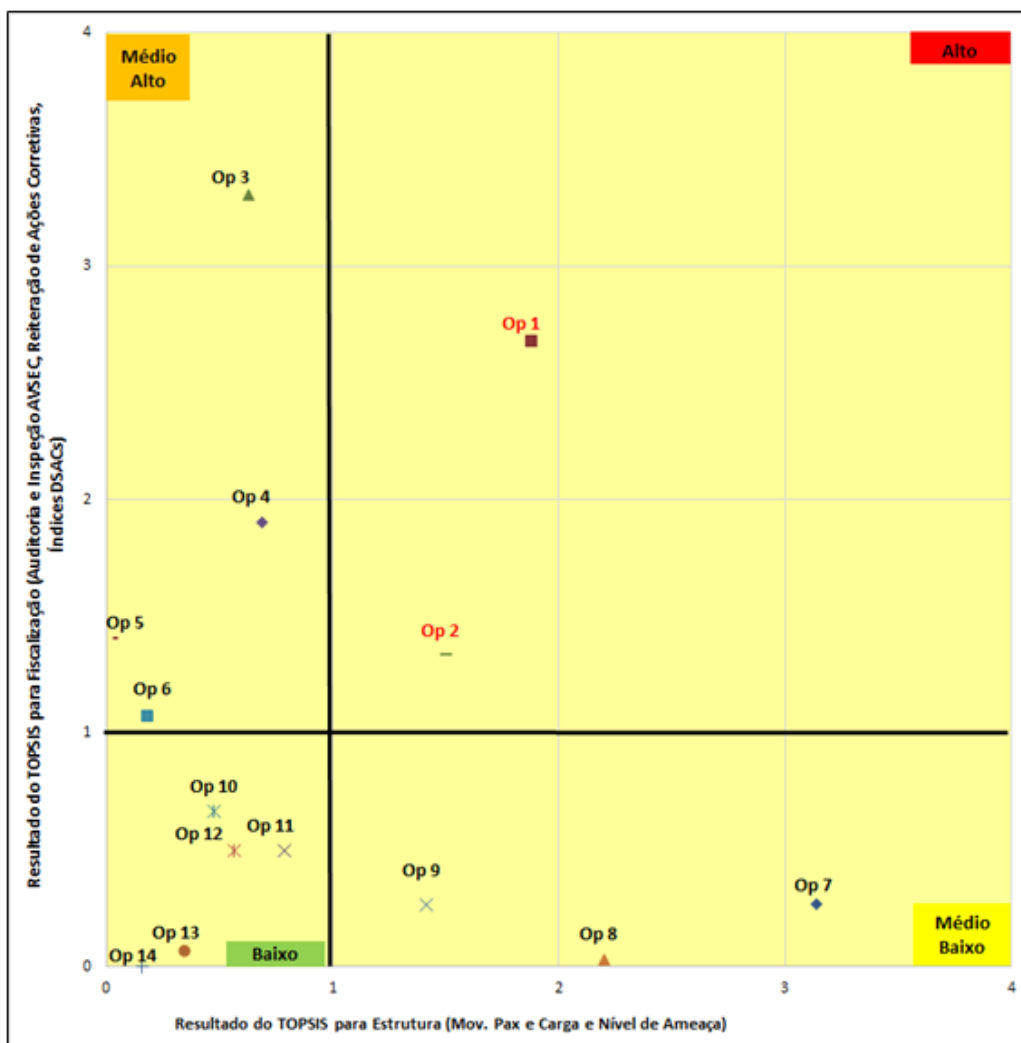


Figure 4. Sample Dispersion Graph

The advantage of using the Dispersion Graph is the possibility of indicating which air operators would be prioritized in AVSEC activities based on information from different data sources, as well as helping to guide which AVSEC activity would be more appropriate based on the air operator's position on the graph.

## 4. RESULTS

### 4.1. Airlines Safety under RBAC n° 121

Risk profile for each RABC 121 operator will be assessed in three layers. Results from each step will be used to drive oversight planning cycle, proportionally distributed considering available workforce:

First step is to determine specific operator's risk profile to capture risk associated to operator size, complexity and nature and usually not variable with each individual organization performance, such as number of aircraft, station, technical staff, approved special operations, etc. An initial planning of surveillance activities is set from those criteria and no improvement has been proposed in this field as mostly previously method has been used. This initial step represents around one third of total annual inspections and audits.

Further, new criteria have been introduced to enhance risk profile and also add past performance definition to capture risks dependent to specific operator behavior through specific developed tools, such as: financial situation, management rotation, transparency, corrective measures performance, operation experience, significative expansion or retraction, past certifications performance, etc. The main contribution of this work is concentrated in this second step, that will represent around one third of yearly activities.

For the final step that is the subjective planning made by the Subject Matter Expert (SME) in the specific SMS field (Organization, Flight Operations and Training, Flight Dispatch, Cabin Service and Ground Operations) and operator for every quarter, a Job Aid checklist tool has been developed to support the tactical planning that will update the annual planning cycle to reassess each operator risk profile and performance and tackle specific short terms risks through new surveillance activities. Except for Cabin Service and Flight Dispatch fields, due to manpower constrains, this portion will address around one third of yearly activities, which has been established as an initial premise to drive first and second steps planning.

Three different tools presented in Chapter 3.1 have been developed to achieve our main objective to capture risk profile and the performance in managing risks for each operator and support the second and third steps of RBAC 121 operators' surveillance planning presented above:

1. Quiz to objectively qualify an operator performance by safety experts from the authority;
2. Objective criteria table to quantify an operator risk profile, and;
3. Job aid to support tactical subjective planning based on perceived operator performance by the experts.

#### **4.1.1. Results**

Proposed methodology has been applied to build 2022 annual cycle oversight planning for ANAC Air Transport Operations (equivalent to Federal Aviation Administration – FAA, CFR 14, Part 121). Final outcome achieved through weights and factors calculation to adjust operator risk proportional to individual organization profile and past performance, considering human resources available for each area to be inspected or audited. Thus, initially surveillance sample based only in the organization risk profile and complexity (first step) is adjusted by ponder factor to increase (high risk) or decrease (lower risk) the number of activities for each area of oversight (second step), always respecting the given constrain of manpower available for next year.

Several interactions were required to come to the final result in terms of weights and factors, specially to cope with initial premise of leaving one third of available human resources to the third step (tactical). An Excel datasheet has been used for the final calculations and final planning.

Around 600 surveillance activities have been planned based on the developed methodology in the following airline operations areas during steps one and two:

- Pilot/Cabin Service/Flight Dispatch operations, training and evaluation;
- SMS;
- Organization and station audits;
- Ground handling, and;
- Dangerous Goods.

Finally, around 300 surveillance activities are set open as unplanned to be used for the third step that will update annual planning every quarter in a more tactical and ad hoc approach based on the current risk perception and judgment from the SMEs in charge of each operator and SMS field.

Only main base and SMS audits activities have not been considered for the presented methodology due the related specific scope and nature that makes this kind of activities more comprehensive and frequency dependent.

#### 4.1.2. Improvements on current methodology

After implementing developed methodology, we expect to deliver the following improvements to current methodology:

- More objective methodology that incorporated qualitative criteria previously present in a more subjective and non-standardized approach;
- More accurate planning adjusted to individual operators' risk profile and performance in controlling specific operations risks, with the benefits of better managing public resources;
- Model to replicate same methodology for the next years' planning.

#### 4.2 Training Organizations under RBAC n° 141

The methodology presented in section 3.2 was used in planning the CATOs surveillance actions for the year 2022.

In the first stage, 38 CATOs, out of a universe of 307 certified ones, have been identified to be oversights as a result of the frequency in which the regulator must inspect or audit the regulated entity.

Indicator	#CATOs	Criterion
CATO type 1	25	Duration of the inspection cycle
CATO type 2	13	Duration of the inspection cycle
<b>Total</b>	<b>38</b>	

*Table 5.* Indicators of the first stage of CATO RBO planning methodology.

In the second stage, each indicator used selected the number of CATOs showed in the table below, according to the established criteria, observed in the period relative to the last three years, except for the last indicator, for which the records of the last five years were observed. The cut-off criteria were suppressed as they are not relevant for the understanding of the methodology application.

<b>Indicator</b>	<b>#CATOs</b>	<b>Criterion</b>
Success in the theoretical exam applied by ANAC	15	Pass rate of students on first attempt below X%
Number of students graduated in flight courses for private pilot of airplane - PPA	8	Y% of the total number of PPA graduated in the country
Number of students graduated in flight courses for private pilot of helicopter - PPH	9	Y% of the total number of PPH graduated in the country
Number of hours of flight training for private pilots of airplane	10	Less than Z hours in the mean
Number of hours of flight training for private pilots of helicopter	12	Less than Z hours in the mean
Occurrences of accidents and incidents	7	CATOs with higher incidence of occurrences
<b>Total</b>	<b>61</b>	
<b>Total (single count)</b>	<b>50</b>	

*Table 6.* Indicators of the second stage of CATO RBO planning methodology.

From the 61 CATOs identified, 11 have been elected due to more than one indicator, so that 50 CATOs are eligible to compose the oversight plan for 2022. Thus, some CATOs will undergo more than one type of surveillance.

Finally, a subjective analysis by the department managers was carried out and it was concluded that the 88 CATOs brought up in stages 1 and 2 should be maintained in the plan, and some of them will receive more than one type of surveillance action. There are five types of surveillance actions, which are variations of the more comprehensive type, with an in-depth look at specific topics. Any surveillance needs of certain CATOs raised during the subjective analysis, as a result of previous surveillance actions, denunciations stock or history of the behavior of the regulated company with the regulator, resulted in the inclusion of a new type of inspection for the CATOs already listed in the previous stages, instead of adding new CATOs to the plan.

The reserve of unplanned inspection actions for 2022 is 40, consistent with the average of last years. Usually, the plan is fed with an average of 30 unplanned actions related to complaints/denunciations and 10 related to occurrences.

The 2022 CATOs surveillance plan generated from the risk-based oversight (RBO) planning methodology seemed quite adequate, reflecting the perceived risk in this segment. The indicators used in stage 2 focused on aspects deemed priority by the responsible technical department at the moment. Each year the set of indicators must be reassessed and changed, if necessary, as well as the cut-off criteria, as the issues that make up the risk perception are being dealt with and others become a priority. This is nothing more than the reflection of the risk

perceived by the regulatory authority, which is dynamic, totally consistent with the idea of RBO.

#### **4.2.1. RBAC n° 141 and RBO future improvements**

The composition of the risk profile of the regulated companies must reflect the risk perception of that segment. It is natural that the perceived risk changes over time and, consequently, the indicators that will lead to the definition of the risk profile must be adapted to capture the new reality.

In the case of CATOs, it is expected that the indicators presented in this work are used in the next year planning for the subsequent cycle, at least. However, possibilities for improvements are already identified, such as:

1. Add the indicator of the regulated company safety management system (SMS) maturity. Knowing the ability of the regulated company to identify and address risks on its own leads to more objective and effective oversight. Important work of acculturation must be done with the CATOs for the correct implementation of the SMS, which is already present in most of them. Likewise, the regulator's tools for guidance and evaluation of the regulated companies' SMS must be adapted;
2. Evaluate the gains to the methodology of subdividing the CATOs type 2 classification according to fleet size and aircraft models used in the training;
3. Develop indicators related to the performance of accredited pilot examiners linked to CATOs. These professionals are responsible for almost all flight checks of CATOs students, which means that they assess and attest the quality of the training;
4. Develop indicators of characteristics and performance of aircraft maintenance mechanics courses;
5. Develop indicators relating occurrences (accidents/incidents) to CATOs where the pilot has been trained and to the CATOs' fleet size and flight hours;
6. Evaluate the gains to the methodology of including an indicator of the number of students graduated in theoretical courses, regardless of their success in the exams, similar to the indicators of number of students graduated in private pilot flight courses.

Some improvements can be incorporated into the methodology as soon as solutions are available, while other indicators can be built and monitored and only used in surveillance

planning when the department managers understand adequate according to the perceived risk in the segment.

Regarding the subjective assessment, stage 3 of the methodology applied to the CATOs, it is desirable that the responsible department controls the progress of the outputs of previous surveillance actions in a way that allows for more direct use in future planning. Besides, denunciations data collection and assessment could be structured to ease their use in the RBO planning. It is also worth discussing a more structured way to carry out the stage 3 assessment.

In general, it is desirable that each year the methodology undergoes a critical analysis by the department managers in order to assess its adequacy and reasonableness. It is important to keep in mind that the methodology seeks to optimize the use of available resources, prioritizing surveillance actions based on the sector's perception of risk. The output of the planning methodology cannot be the mere generation of a list of entities to be audited or inspected, but rather represent the surveillance of aspects that actually pose greater risk to the system at that moment.

#### **4.3. Airlines Security under RBAC n° 108**

With a large number of airlines to be evaluated (same those under RBAC 121), it was decided to segregate nationals from foreigners operators in the analyses. In addition to this segregation, a restriction must be considered before starting the TOPSIS methodology: for the Air Operator Structure, do not use the variables “Total Domestic Passengers” and “Total Domestic Cargo” for the analysis of foreign airline operators. The “Threat Level” calculated and provided by the Federal Police for the air operators was used. For "Quality Control Data" on this analysis, auditing and inspection activities, on site or remotely, as well as the reports carried out by ANAC were considered. Results were prioritized after corrective actions for irregularities found and not the image of the result at the time of the activity.

For analysis using the TOPSIS methodology, the variables collected in the following periodicities were considered:

- Domestic and international passenger and cargo: from January 2019 to May 2021;
- Threat level: analysis carried out in 2019;

- Audit and Inspections data: from January 2018 to June 2021;
- Reports: from January 2019 to June 2021.

The results achieved with the TOPSIS methodology are presented in item 4.3.1 in the form of Dispersion Graphs, for national and foreign air operators.

#### **4.3.1. Results**

Due to the confidentiality of the results of the AVSEC risk assessment, considering as restricted security information, the identification name of airlines companies was mischaracterized in the results presented in this research, especially in the Dispersion Graphics. Complete information is only disclosed within ANAC's internal scope to employees who need the information, in accordance with the need-to-know principle.

The analysis by the TOPSIS methodology for national air operators was evaluated 8 (eight) airlines. Passenger and cargo movements are heterogeneous among these eight national companies, but some stand out for also operating passengers on international flights and international cargo.

None of the national airlines were positioned in Quadrant 2 (high risk). In Quadrant 1 (medium-high risk) 2 (two) companies stand out, which have low structure and obtained a high level of vulnerability in the TOPSIS, that is, many items considered irregular in the audit and inspection actions. In Quadrant 4 (medium-low risk), 4 (four) companies were positioned, which present a large structure and a low verified vulnerability, and in Quadrant 3 (low risk) 2 (two) companies were positioned with low structure and low verified vulnerability. This results is displayed in Figure 5.

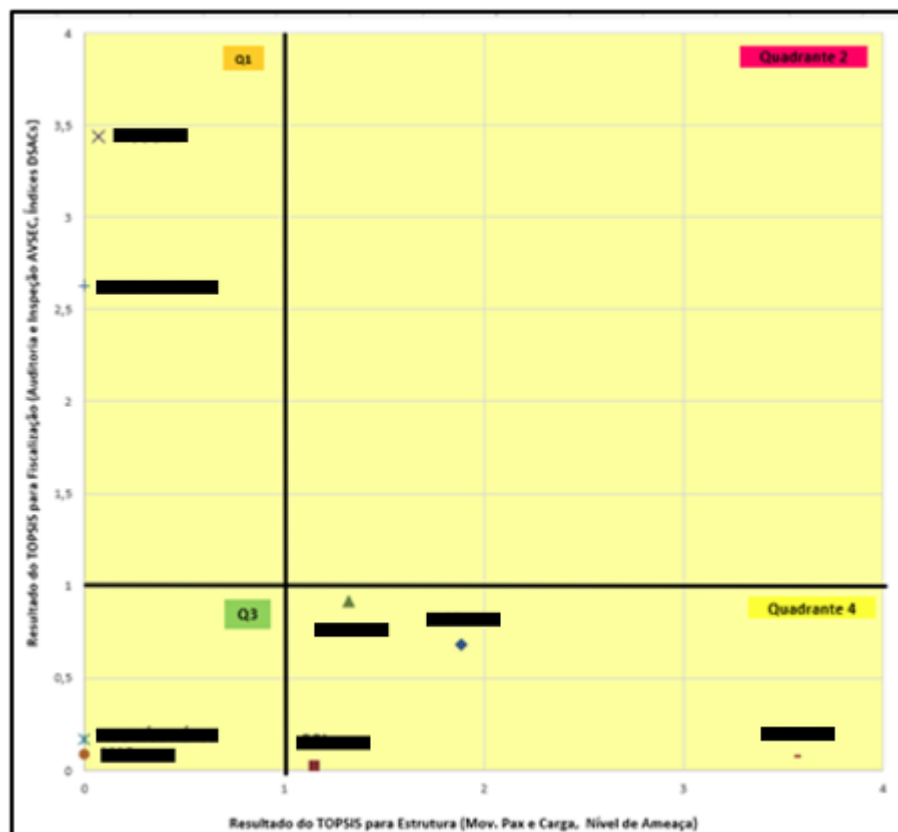


Figure 5. National Airlines Dispersion Graph

The analysis by the TOPSIS methodology for foreign air operators evaluated 42 (forty-two) airlines. Most of the data collected for this analysis comes from the years 2018-2019, considering that in 2020-2021 the Covid-19 pandemic considerably impacted the operation of international flights and the performance of oversight activities on foreign operators.

Foreign operators were concentrated in Quadrant 3 (low risk) with 22 (twenty-two) companies with low structure and low verified vulnerability. Then there are 11 (eleven) companies in Quadrant 4 (medium-low risk) that have a high structure and a low verified vulnerability. In Quadrant 1 (medium-high risk) there are 6 (six) companies, which have a low structure and a high level of vulnerability. Finally, there are 3 (three) companies in Quadrant 2 (high risk), considered to be of higher risk, as airlines have a high structure and a high level of vulnerability. The result of the analysis using the TOPSIS Methodology is illustrated in Figure 6.

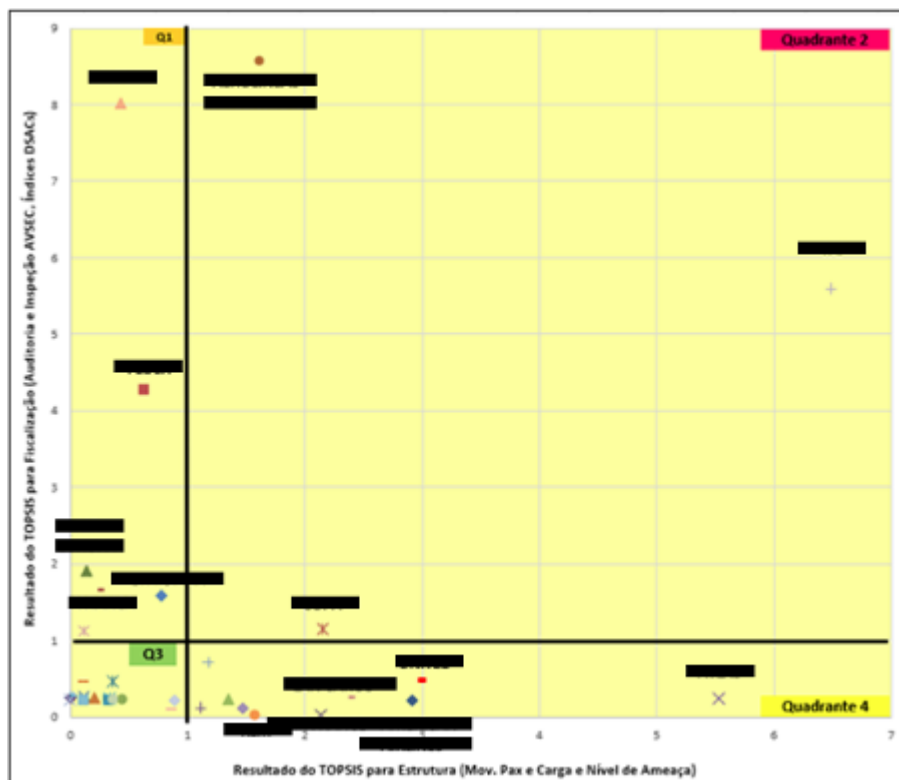


Figure 6. Foreign Airlines Dispersion Graph

### 4.3.2 Future Improvements

As future improvements for the application of the TOPSIS methodology aimed at the AVSEC risk management of airlines, it is suggested to use data collected by the airlines themselves in their internal AVSEC quality control activities, as well as data from the AVSEC Tests carried out by ANAC in the airline operators that were resumed in 2021.

Another point for improvement suggested is related to an adjustment in the scale of the Dispersion Graphs, considering that companies that have very different structures (number of passengers and cargo transported, "x" axis) are very distant in the graph, reaching some operators are practically "isolated" in the dispersion.

## 5. CONCLUSION

Our main research objective was to develop methodologies to support oversight activities planning based on risk profile and safety/security performance for different segments (RBAC 121, 141 and 108) regulated by ANAC. However, it is important to notice that besides planning and execution, collected data risk assessment, classification and treatment after inspections and audits are crucial to reach the final goal of properly controlling aviation risks. More than that, depending on the segment, additional new data must be collected to allow for a better risk assessment. Initial expectation to contribute to supporting RBO implementation at ANAC and a more efficient way of allocating government resources has been accomplished as next year's surveillance planning for training organizations and airlines security and operations has delivered a more intelligent planning process based on objective criteria, prioritizing and tailoring oversight activities based on individual service provider risk profile. At the same time, the methodologies are flexible, once the indicators that make up the risk profile and performance assessment may be easily adjusted to reflect the risk perceived by the regulator in a given moment, which is dynamic. We found that RBO is still under customized solutions among different regulators, therefore, after studying cases that are already being successfully executed, adapted objective methodologies have been proposed to be used by ANAC in three specific fields: airlines security, airlines operations and training organizations.

As future work opportunities, results presented by Shyur (2008) could be considered in future improvements to the methodologies proposed here. It would demand more data collection, integration and assessment to better understand service providers hazards and risks. Another possible research opportunity is to go deeper in a more objective system to classify operator risk management performance.

Other important step that comes further is the discussion and finding solutions process with collaborative service providers' participation to implement and follow up efficient corrective measures.

Considering that only after 2016 regulators have started releasing policies for RBO, one limitation found during our research was the lack of practical references in this field. Therefore, our strategy was to focus on other authorities' principles and procedures benchmarking.

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