REVIEW

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The impact of the application of the Simplified Final Report (SFR) on the investigative processes of aeronautical occurrences of military aviation carried out by CENIPA

El impacto de la adopción del Informe Final Simplificado (RFS) en los procesos investigativos de sucesos aeronáuticos de la aviación militar, conducidos por el CENIPA

O impacto da adoção do Relatório Final Simplificado (RFS) nos processos investigativos de ocorrências aeronáuticas da aviação militar, conduzidos pelo CENIPA

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ABSTRACT

The Aeronautical Accidents Investigation and Prevention Center (CENIPA) has implemented measures to increase the speed of the investigation process of aeronautical occurrences. In this context, the present study aimed to verify the extent to which the application of the Simplified Final Report (SFR) impacted on the amount of final military reports produced by CENIPA in the first nine months of 2015. The focus of the study was to verify if the production capacity of final reports by CENIPA has changed after the application of the SFR for the investigation of military occurrences. The analysis was based on the statistical correlation between two periods of equal duration, one before and one after the application of the SFR. To quantify the impact on production capacity of final reports, an indicator that related the number of reports initiated and finalized in each period of the survey was applied. The indicator showed an increase of 58,86% in the production capacity of final reports after the application of the SFR in the field of military aviation from January to September 2015. The increase was confirmed by the Chi-Square statistical test, which confirmed the statistical significance among the variables and detected a correlation between the number of reports completed by CENIPA and the application of the SFR, at the level of significance established in this research.

Keywords: Production capacity. Simplified final report. Final report. Military aviation.

RESUMEN

El Centro de Investigación y Prevención de Accidentes Aeronáuticos (CENIPA) ha adoptado medidas que aumenten la celeridad de los procesos de investigación de sucesos aeronáuticos. En este contexto, la presente investigación tuvo por objetivo verificar en qué medida la adopción del Informe Final Simplificado (RFS) impactó en la cantidad de informes finales militares producidos por el CENIPA, en los nueve primeros meses del año 2015. El foco del estudio residía en verificar si la capacidad de producción de informes finales, por el CENIPA había sufrido alteraciones después de la adopción del RFS para la investigación de ocurrencias militares. El análisis se basó en la correlación estadística entre dos períodos de igual duración, uno anterior y otro posterior a la adopción del RFS. Para cuantificar el impacto en la capacidad de producción de informes finales, se utilizó un indicador que relacionó la cantidad de informes iniciados y finalizados en cada período de la investigación. El indicador mostró un indicio de aumento del 58,86% en la capacidad de

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The acronyms of the words Simplified Final Report (SFR) and Final Report (FR) were employed in English. The other acronyms and abbreviations contained in this article correspond to those used in the original article in Portuguese.

producción de informes finales, tras la adopción del RFS, en el ámbito de la aviación militar, de enero a septiembre de 2015. El aumento se confirmó mediante la prueba estadística de Chi-Cuadrado que confirmó la significación estadística de las variables y se encontró una correlación entre el número de informes terminados por CENIPA y la adopción de RFS para el nivel de significación establecido en este estudio.

Palabras clave: *Capacidad de producción. Informe final simplificado. Informe final. Aviación militar.*

RESUMO

O Centro de Investigação e Prevenção de Acidentes Aeronáuticos (CENIPA) tem adotado medidas que aumentem a celeridade dos processos de investigação de ocorrências aeronáuticas. Nesse contexto, a presente pesquisa teve por objetivo verificar a medida em que a adoção do Relatório Final Simplificado (RFS) impactou na quantidade de relatórios finais militares produzidos pelo CENIPA, nos nove primeiros meses do ano de 2015. O foco do estudo residiu em verificar se a capacidade de produção de relatórios finais, pelo CENIPA se alterou após a adoção do RFS para a investigação de ocorrências militares. A análise se embasou na correlação estatística entre dois períodos de igual duração, um anterior e outro posterior à adoção do RFS. Para quantificar o impacto na capacidade de produção de relatórios finais, foi utilizado um indicador que relacionou a quantidade de relatórios iniciados e finalizados em cada período da pesquisa. O indicador demonstrou um indício de aumento de 58,86% na capacidade de produção de relatórios finais, após a adoção do RFS, no âmbito da aviação militar, de janeiro a setembro de 2015. O aumento foi comprovado por meio do exame estatístico Qui-Quadrado que confirmou a significância estatística entre as variáveis e detectou a existência de correlação entre a quantidade de relatórios finalizados pelo CENIPA e a adoção do RFS, para o nível de significância estabelecido nesta pesquisa.

Palavras-chave: *Capacidade de produção. Relatório final simplificado. Relatório final. Aviação militar.*

1 CONTEXTUALIZATION

After World War II, there was a need to regulate and standardize civil aviation activities in the world, including those for the investigation of aeronautical accidents and incidents. This was determined through the International Civil Aviation Convention, also known as the Chicago Convention, of which Brazil is a signatory. The international treaty, signed in 1944, is in force until the present day. The document created the International Civil Aviation Organization[1] (ICAO) and established, through 19 Annexes to the Convention, standards and best practices recommended for aviation (SOUZA, 2012).

In Brazil, Law No. 7.565/1986, which provides for the Aeronautics Brazilian Code, in its Article 86, says that,

> The Aeronautical Accident Investigation and Prevention System (SIPAER) is responsible for planning, guiding, coordinating, controlling and executing Aeronautical Accident investigation and prevention activities. (BRASIL, 1986, p. 12).

SIPAER has as its central body the Aeronautical Accidents Investigation and Prevention Center (CENIPA), which is responsible for carrying out these activities, in accordance with the aforementioned law.

The sole purpose of the SIPAER investigation is to avoid the occurrence of similar aeronautical occurrences in the future, by identifying contributing factors and issuing safety recommendations, which may eliminate or mitigate those factors. At SIPAER, military aeronautical occurrences are classified into four categories: aeronautical accident, serious aeronautical incident, aeronautical incident and ground occurrence (BRAZIL, 2013).

The final report is the document that concludes the investigation and disseminates the lessons learned from an aeronautical occurrence, and its concept is specified at SIPAER.

> A formal document, intended to disclose the official conclusion of SIPAER, based on the elements of investigation, analysis, conclusion and Safety Recommendations related to an aeronautical accident, serious aeronautical incident, aeronautical incident or ground occurrence, aiming exclusively the prevention of new occurrences. (BRASIL, 2014, p. 13).

The 19 Annexes to the Chicago Convention are divided by specific themes from distinct aviation areas. Issues related to the investigation of aeronautical accidents and incidents are set forth in Annex 13 of the 1944 International Civil Aviation Convention. Section 6.5 of that document states that, in the interest of prevention, the State, in conducting an accident or incident investigation, shall publish a final report in

[1] Organization with 191 member countries whose objective is to develop Recommended Standards and Practices for international civil aviation.

the shortest possible term and, if possible, within a period of twelve months (INTERNATIONAL CIVIL AVIATION ORGANIZATION, 2010). This section highlights the relevance that the Organization assigns to the time factor for the prevention of accidents. Brazil also recognizes time as fundamental factor for the prevention of future occurrences and, for this reason, CENIPA has taken steps to make the investigation process faster and more efficient.

In this context, in 2013, the Simplified Final Report (SFR) was created in the field of civil aviation. The SFR is a simplified version of the Final Report (FR), which enables a faster investigation and compatible with the complexity of the occurrences on which it is applied. The results generated by this initiative were proven by Amancio (2015), who concluded in his research that the application of the SFR accelerated in more than 4 times the processing time of Brazilian civil aviation investigations.

It is important to emphasize that SFR was a tool created to be applied in specific and less complexity cases, and that the FR has not ceased to exist. Both final report models (FR and SFR) contain contributing factors and safety recommendations in their content and, therefore, represent the official conclusion of SIPAER for a given investigation.

The investigation of aircraft accidents in Brazil has a peculiar characteristic to gather in the same organization, CENIPA, the activities related to civil and military aviation. This condition enables the knowledge acquired in the exercise of civil aviation investigations to be applied on military aviation prevention and investigation activities and vice-versa.

Based on the experience of civil aviation in 2013, CENIPA decided to adopt, as of January 1st, 2015, the SFR also for military aviation. This simplified report is being applied to serious incidents, incidents and ground occurrences, and follows reasoning similar to that used when the tool was inserted in the context of civil aviation. For occurrences that are classified as accidents, the FR remains the applied reporting model.

The differences between FR and SFR are not restricted to the report format, because in addition to the document structure, the process of investigating the occurrences has also been simplified. While an accident investigated by means of FR necessarily involves three steps until its investigation is considered complete, the minor incidents that are investigated through SFR cover only two stages. Therefore the process gains in speed and efficiency.

The time spent to produce a final report (whether FR or SFR) is of major importance in the context of accident prevention, since the publication of these reports is one of the main ways CENIPA uses to work directly with military aviation actors. It can be inferred, therefore, that the faster the research process is, the more quickly the lessons learned will be disseminated and sooner the research cycle will be finalized (AMANCIO, 2015).

The speed of military investigations is directly related to the production capacity of the CENIPA's Investigation Subdivision (SDINV). In the scope of this paper, the term **production capacity** means the amount of final reports that CENIPA can produce in a given period of time.

To date, no assessment has been made of the impact that the application of SFR has had on CENIPA's ability to produce final reports in the field of military aviation. By acting directly in the conduction of investigation processes of CENIPA, the following question arose and corresponds to the general objective of this work: to what extent did the application of the Simplified Final Report (SFR) have an impact on CENIPA's capacity to produce final reports on military aviation, from January to September 2015?

For data collection and analysis, two distinct periods were considered, as described below:

a) Before Application (AA) - from January 1st to September 30th, 2014; and

b) After Application (DA) - from January 1st to September 30th, 2015.

In order to achieve the general objective, three guiding questions were elaborated:

GQ1: How many military FR and SFR were initiated in the AA and DA periods, respectively?

GQ2: How many (FR) were finalized in the AA period, in the scope of military aviation?

GQ3: How many (SFR) were finalized in the DA period, in the scope of military aviation?

The resolution of these questions aims to achieve the specific objectives listed below:

SO1: Identify the amount of military FR and SFR initiated in each of the established periods.

SO2: Identify the amount of FR finalized in AA period, within the scope of military aviation.

SO3: Identify the amount of SFR finalized in the DA period, within the scope of military aviation.

The importance of this paper lies in quantitatively verifying whether there was evolution in the speed of the investigation process of Brazilian military aeronautical occurrences, after the application of SFR. This evolution is significant in the current context of the Brazilian Air Force (FAB) and the Brazilian State regarding the economy of resources and maximization of results in government entities. Additionally, CENIPA's military turnover is quite high, and every time a replacement happens, the substitute takes a significant amount of time to understand the process. A model that is faster and more efficient suffers less from the consequences of the researchers' turnover.

CENIPA has a greater research demand in civil aviation than in military, but it needs to be of equal intensity in both segments so that safety levels remain the same. Thus, the more similar the processes are, the more uniform the results will be.

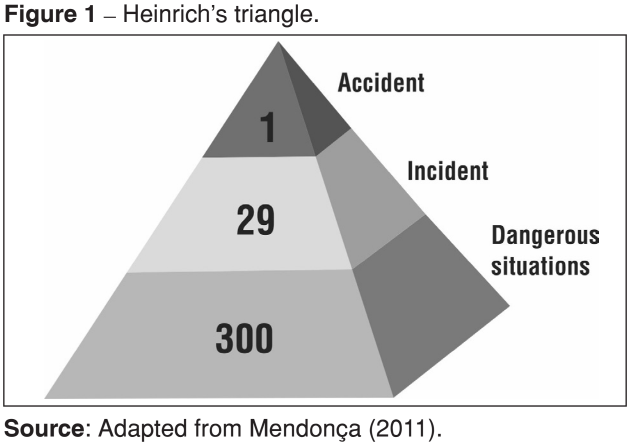
Finally, the results of this research can help the Aeronautics Command (COMAER) and CENIPA itself in the planning of staffing and its distribution within the Center, in addition to allowing an analysis of the effects of the new) adopted report (SFR) and ratifying its use in the investigation of military aeronautical events.

2 THEORETICAL REFERENCE

2.1 Heinrich's Triangle Theory

In the 1950s, Heinrich and Granniss developed a theory that became worldwide known as Heinrich's Triangle, Figure 1. In this study, the researchers analyzed thousands of occurrences and concluded that for every accident with injuries or deaths, hundreds of other similar minor events occur, without injuries or fatalities. The focus of this theory is that events of lesser complexity can and should be identified and controlled before they evolve into more serious events that may result in injury, fatalities or material damage (MENDONÇA, 2011).

Figure 1 – Heinrich's triangle.



Source: Adapted from Mendonça (2011).

Other theories establish different reasons between accidents, incidents and dangerous situations, but also describe that these occurrences have similar reasons, differing only by the consequences they generate. The major contribution of these theories is that less serious cases (dangerous situations and incidents) are considered precursors of accidents and should be investigated (MENDONÇA, 2011).

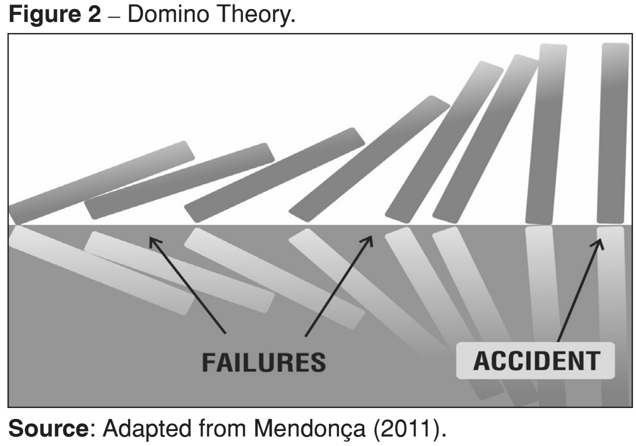
Heinrich's Triangle theory supports the studies of this paper because it emphasizes that the events at the base of the pyramid, when properly and timely investigated, are mitigated before they evolve into a condition of events with more serious consequences. In the case of military aeronautical occurrences, the base of the pyramid is formed by ground occurrences, incidents and serious incidents. By improving the efficiency of the investigation process of these events, CENIPA is acting directly in the prevention of accidents, located at the top of the pyramid.

Based on the theory presented, it was possible to analyze the behavior of the distribution of military occurrences in the AA and DA periods, which will be explored in item 4 (Analysis) of this paper.

2.2 Domino theory

The domino theory (Figure 2), also developed by Heinrich, defends the idea that an accident is the result of a chain of events that occur in logical sequence. These events can be represented as if they were pieces of dominos lined up one after another. The fall of one of the dominos pieces means the occurrence of a failure, which will lead to the fall of a second piece (another fault) and, in this way, successive failures will happen until all the pieces have been knocked over, making the accident inevitable (MENDONÇA, 2011).

Figure 2 – Domino Theory.



Source: Adapted from Mendonça (2011).

The main concept attached to this theory is that, by removing a piece from the sequence of dominos, the accident will be avoided (HEINRICH; GRANNIS, 1959 apud MENDONÇA, 2011).

The relationship between this theory and the present paper is evidenced by the fact that the piece to be removed may have been identified during the investigation of an earlier occurrence, whether it is an accident, an incident or a ground occurrence. By increasing the production of final reports, consequently the chance of identifying contributing factors (domino pieces) that will lead to the application of mitigating actions is increased. These mitigating actions represent the withdrawal of a piece from the sequence of dominos and the consequent interruption of the chain of events, helping to prevent future accidents.

2.3 Theory of organizational accidents

James Reason, a renowned researcher in the subject of human errors, presented in 1997 the Swiss Cheese model for organizational accidents (Figure 3). Reason's theory (1997) points out that complex systems are protected by multiple defense barriers in order to prevent risky situations from evolving into an accident. However, these barriers have weaknesses that, when manifested in latent failures, may allow the occurrence of a catastrophic event. In this theory, the barriers are like slices of a Swiss cheese, and its weaknesses are represented by the cheese holes in the slices. According to the theory presented, these conditions are independent of the complexity of the occurrence, so that simple occurrences have latent conditions as well as more complex occurrences (REASON, 1997).

The Swiss Cheese theory was widely accepted in the aeronautical community and is, to the present day, used to aid in the investigation of aircraft accidents around the world. The connection between this research and Reason's theory consists in identifying latent failures during the investigation of occurrences. The expansion of the possibility of identifying latent failures is a direct consequence of the increase in the capacity to produce final reports. The mitigating actions of these failures in the defense barriers represent the obstruction of the holes (failures) of the cheese slices (barriers), contributing to the prevention of future accidents.

3 METHODOLOGY

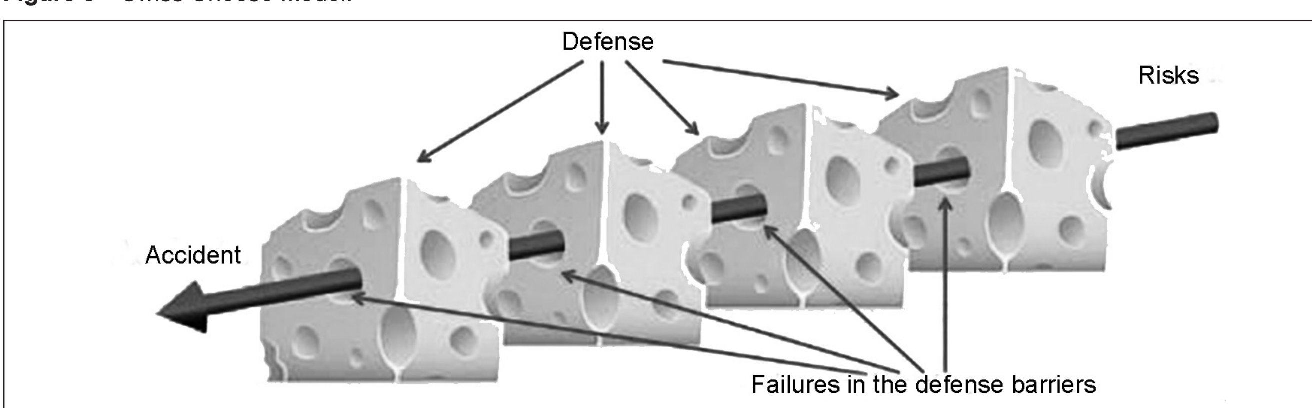
Given the general objective and, according to Gil (2002), this research was classified as descriptive, since it established the relationship between the application of SFR and the production capacity of investigation reports by CENIPA, in the two periods specified in this paper.

In order to introduce the subject, a literature review of the main theories regarding the causes of accidents and incidents in complex systems was carried out, linking these theories to the activities developed by CENIPA, in the scope of the investigation of military aeronautical occurrences.

As for the technical procedures, the research design was classified as a documental, according to Gil (2002), for collecting data on the statistical bases of military aeronautical occurrences and on the final report production records of the Investigation Subdivision () of CENIPA Operational Division (DOP).

In order for the results to be proportional and allow for a uniform analysis, two equal time intervals were considered, one prior and one subsequent to the application of the SFR.

Figure 3 – Swiss Cheese Model.



Source: Adapted from Reason (1997).

a) Before Application (AA) - from January 1st to September 30th, 2014; and

b) After Application (DA) - from January 1st to September 30th, 2015.

This research was conducted in the course of 2015, coinciding with the DA period. For this reason, the periods considered for data collection and analysis were extended until September 30th in both cycles, which is a limitation of the paper.

From the entire universe of military aviation investigations, the sample of this paper corresponds to the 105 (one hundred and five) FR initiated and 26 (twenty six) FR finalized in the AA period; and to the 116 (one hundred and sixteen) SFR initiated and 97 (ninety seven) SFR finalized in the DA period.

The research carried out in the CENIPA database allowed the identification of quantitative military FR and SFR processes initiated in both periods. These information led to the answer to the first guiding question and, consequently, to the scope of the first specific objective. The data obtained were organized by type of occurrence classification (accident, serious incident, incident and ground occurrence) in order to ascertain the behavior in relation to the distribution.

Aiming to answer the second and third guiding questions, we verified the quantitative of FR and SFR finalized in the AA and DA periods, respectively. At the end of the data collection, the figures obtained led to the answer to guiding questions 2 and 3 and, consequently, to the achievement of the second and third specific objectives. Based on the known data, an exploratory analysis of the scenario was conducted, comparing the production capacity in each of the established periods. To quantify the data, an indicator called Military Occurrence Investigation Index (IIOM) was used, defined according to Equation 1.

$$IIOM = \left(\frac{\sum x_i}{\sum y_i}\right) \text{ x } 100 \qquad (1)$$

Where,

$IIOM$ = Military Occurrence Investigation Index;

$\sum x_i$ = number of final reports finalized in each period; and

$\sum y_i$ = number of final reports initiated in each period.

The $IIOM$ relates the quantity of FR/SFR initiated with the quantity of FR/SFR finalized in each period. Equation 1 was applied for determination of $IIOM_{AA}$ e $IIOM_{DA}$. The analysis of the difference between the values was performed, according to Equation 2.

$$\Delta IIOM = IIOM_{DA} - IIOM_{AA} \qquad (2)$$

The result of Equation 2 demonstrated in percentage terms an indication of dependency between the application of SFR and the production capacity of CENIPA. However, it was necessary to test this hypothesis to conclude whether this indication was statistically significant. For this end, the Chi-Square statistical test (X^2) was conducted, which is detailed below.

3.1 Chi-square test (X^2)

According to Ryan (2009), the Chi-Square statistical test (X^2) was applied on the data obtained in the research. The author states that the X^2 test is applicable when the data is presented in the form of frequency. The purpose of the test is to detect statistical significance of the difference between two or more independent groups, i.e., to test the independence between two or more variables.

For the application of the test, it is necessary to validate the following requirements in the data set:

a) measurement level on a nominal scale;

b) in 2x2 tables, the expected frequencies must be greater than 5; and

c) the groups compared must be independent.

The test was performed considering two hypotheses, they are:

λ_0 : the variables are independent; and

λ_1 : the variables are not independent, i.e., the behavior of one interferes in the other.

The null hypothesis (λ_0) was tested using Equation 3.

$$X^2 = \sum_{i=1}^{k} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \qquad (3)$$

Where,

k = number of groups;

O = observed frequency; and

E = expected frequency.

The calculation to find the expected frequencies is given by the rule, according to Equation 4.

$$E_{ij} = \frac{\sum \textit{line } i \text{ x} \sum \textit{column } j}{\textit{total sum}} \qquad (4)$$

The degrees of freedom are defined by Equation 5.

$$gl = (\text{number of lines} - 1) \text{ x } (\text{number of columns} - 1) \qquad (5)$$

3.1.1 Application of test X^2

First the data have been collected through the answers of the three guiding questions.

The results obtained correspond to the observed frequencies, according to Table 1.

Table 1 – Table of observed frequencies.

Period	initiated FR/SFR	finalized FR/SFR
AA	O_{11}	O_{12}
DA	O_{21}	O_{22}

Source: The author.

Once the values of the observed frequencies (O_{11} , O_{12} , O_{21} and O_{22}), have been known, the sums of the rows and columns of the table, necessary for the application of Equations 6 to 9, have been calculated.

$$\sum line\ 1 = O_{11} + O_{12} \quad (6)$$

$$\sum line\ 2 = O_{21} + O_{22} \quad (7)$$

$$\sum column\ 1 = O_{11} + O_{21} \quad (8)$$

$$\sum column\ 2 = O_{12} + O_{22} \quad (9)$$

The sums found can be arranged according to Table 2.

Table 2 – Observed frequencies with total sums.

Period	Production Capacity		
	initiated FR/SFR	finalized FR/SFR	Total
AA	O_{11}	O_{12}	$\sum$ *line 1*
DA	O_{21}	O_{22}	$\sum$ *line 2*
Total	$\sum$ *column 1*	$\sum$ *column 2*	*Total sum*

Source: The author.

From Equations 6 to 9, the expected frequencies E_{11}, E_{12}, E_{21} and E_{22} are obtained, according to Equations 10 to 11.

$$E_{11} = \frac{\sum line\ 1\ x \sum column\ 1}{total\ sum} \quad (10)$$

$$E_{12} = \frac{\sum line\ 1\ x \sum column\ 2}{total\ sum} \quad (11)$$

$$E_{21} = \frac{\sum line\ 2\ x \sum column\ 1}{total\ sum} \quad (12)$$

$$E_{22} = \frac{\sum line\ 2\ x \sum column\ 2}{total\ sum} \quad (13)$$

Once the expected frequencies were known, the data obtained were validated, according to the requirements **a**, **b** and **c** of the test, arranged in item 3.1.

Finally, after obtaining and validating all the data, it was possible to perform the statistical test X^2 calculation, as well as the degrees of freedom of the applied statistics. The X^2 value calculated was compared with the critical value of X^2 tabulated (Figure 4), considering the level of significance of 0,05 ($\alpha = 5\%$). The comparison of X^2 values follows the criteria indicated in Equations 14 and 15.

$$X^2\ calculated > X^2\ tabulated = \lambda_0;\ rejected \quad (14)$$

$$X^2\ calculated < X^2\ tabulated = \lambda_0;\ true \quad (15)$$

The rejection of a hypothesis validates the other hypothesis with a degree of reliability of 95%, since the level of significance established for the test was 0.05 ($\alpha = 5\%$).

The comparison between the value of X^2 **calculated** and the value of X^2 **tabulated** subsidized the analysis and the understanding of the obtained result, elucidating the general objective of this work and responding to the research problem.

Figure 4 – Critical values of X^2.

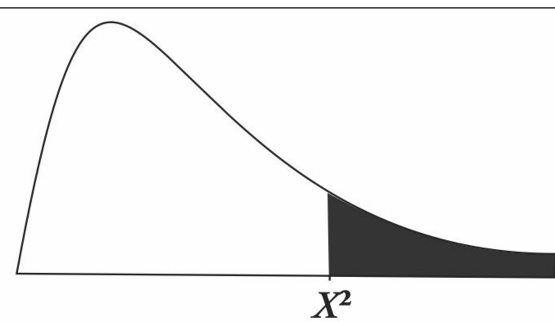


Table C: X^2 critical values

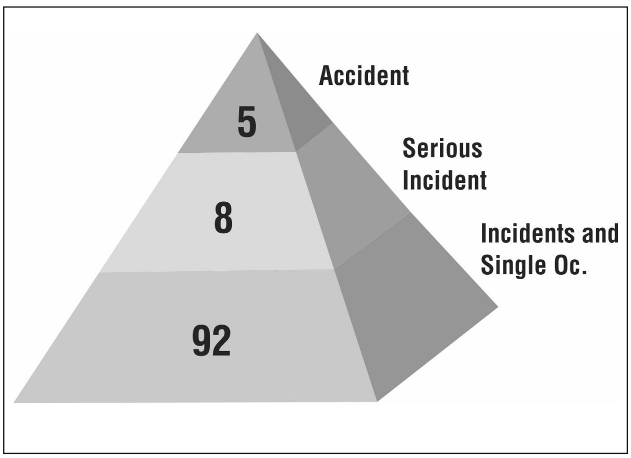
gl	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001
	P tail probability										
1	1.32	1.64	2.07	2.71	3.84	5.02	5.41	6.63	7.88	9.14	10.83
2	2.77	3.22	3.79	4.61	5.99	7.38	7.82	9.21	10.60	11.98	13.82
3	4.11	4.64	5.32	6.25	7.81	9.35	9.84	11.34	12.84	14.32	16.27

Source: Adapted from Ryan (2009).

4 ANALYSIS

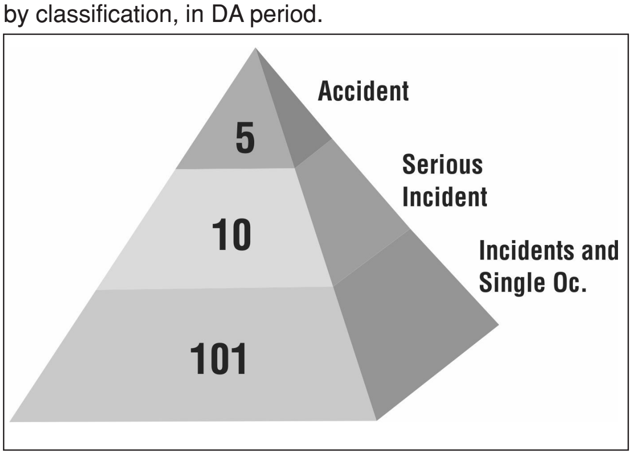
In order to investigate the proposed problem, we performed analysis and interpretation of the data, based on the theoretical framework and methodology presented. Initially a direct analysis of the distribution of the military aeronautical occurrences was carried out, regarding its classification, in AA and DA periods. Although the ratio between occurrences was not exactly as Heinrich's triangle theory describes in the theoretical reference, the pyramid-shaped distribution could be observed, as shown in Figures 5 and 6 below.

Figure 5 – Distribution of military aeronautical occurrences, by classification, in AA period.



Source: Adapted from MENDONÇA (2011).

Figure 6 – Distribution of military aeronautical occurrences, by classification, in DA period.



Source: Adapted from MENDONÇA (2011).

The distribution presented corroborates the theoretical reference. The increase in the production capacity of final reports of the occurrences located at the triangle base makes it possible to determine a greater amount of contributing factors and latent faults represented by the dominos and holes in the cheese slices of the theories discussed above.

The next step consisted of an exploratory analysis of FR and SFR production capacity, per period, as shown in Figure 7. Analyzing this figure, it is noticed that the difference between the number of FR/SFR initiated and the number of FR/SFR finalized is lower in the DA period, compared to the AA period.

If the difference between processes initiated and processes finished is low, it can be concluded that productivity is high and that CENIPA is able to handle the labor demand. On the other hand, if this difference is high, it can be concluded that productivity is small and, consequently, that CENIPA is not able to handle the demand for labor imposed on the Center. It is noteworthy that in both periods, the number of researchers involved in the reporting process was the same.

As a way of estimating the capacity to produce final reports, the IIOM indicator was used in each period.

When applying the values of Figure 7, in Equation 1, the following IIOM were obtained for each period:

$$IIOM_{AA} = \left(\frac{26}{105}\right) \text{x } 100 = 24{,}76\%; \text{ and}$$

$$IIOM_{DA} = \left(\frac{97}{116}\right) \text{x } 100 = 83{,}62\%$$

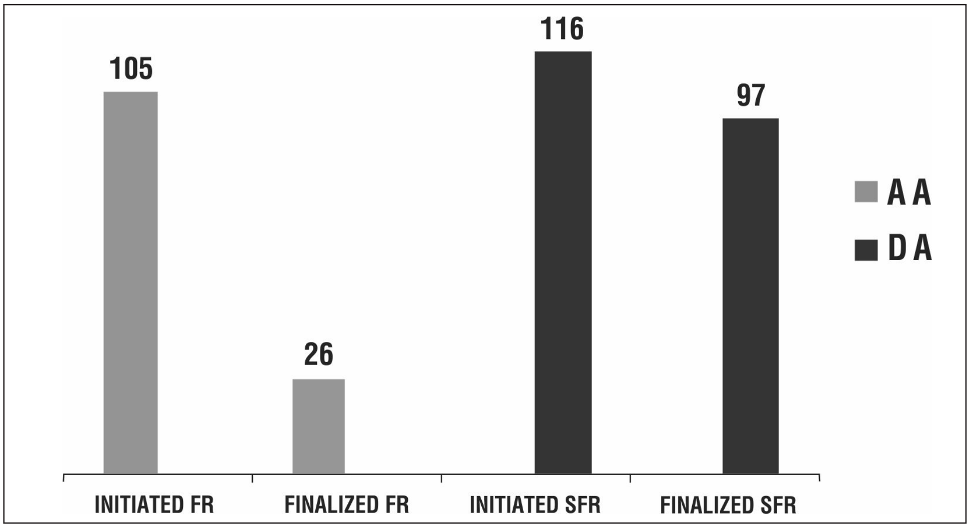
To verify the variation of II0M, Equation 2 was used.

$$\Delta IIOM = 83{,}62\% - 24{,}76\%$$

$$\Delta IIOM = 58{,}86\%$$

The behavior found in the analysis of the IIOM variation shows an increase in the production capacity in the DA period in 58.86%. However, it was necessary to test this hypothesis to conclude whether this indication was statistically significant. The test selected for this verification was the Chi-Square statistical test.

Figure 7 – FR/SFR productivity, by period.



Source: The author.

For the application of the test, the data obtained through the answers to the guiding questions were used. Thus, Tables 1 and 2, with real values calculated, generated to Table 3, which contains the observed frequencies and the sums of rows and columns.

Table 3 – Actual values of observed and summed frequencies of rows and columns.

Period	Production Capacity		
	Initiated FR/SFR	Finalized FR/SFR	Total
AA	105	26	131
DA	116	97	213
Total	221	123	344

Source: The author.

The hypothesis of dependence between the SFR and the capacity to produce final reports was formulated as follows:

- λ_0: the production capacity of final reports did not change with the application of SFR; and
- λ_1: the production capacity of final reports increased after the application of SFR.

To perform the test, it was necessary to know the expected frequencies, which were obtained through Equations 10, 11, 12 and 13.

$$E_{11} = \frac{131 \ x \ 221}{344} = 84{,}15$$

$$E_{12} = \frac{131 \ x \ 123}{344} = 46{,}84$$

$$E_{21} = \frac{213 \ x \ 221}{344} = 136{,}84$$

$$E_{22} = \frac{213 \ x \ 123}{344} = 76{,}15$$

Once the observed frequencies, the expected frequencies and the sum of rows and columns were known, the data were validated, according to the test requirements, set forth in item 3.1. Thus, it is known that:

a) the requirement **a** was met because the data are quantitative discrete;

b) the requirement **b** was also met, since all expected frequency values are greater than 5; and

c) the requirement **c** was met because the data are independent, i.e., the data collected in the AA period do not interfere with the data collected during the AD period.

According to Ryan (2009), it was possible to calculate the X^2 value as follows:

$$X^2 = \frac{(O_{11} - E_{11})^2}{E_{11}} + \frac{(O_{12} - E_{12})^2}{E_{12}} + \frac{(O_{21} - E_{21})^2}{E_{21}} + \frac{(O_{22} - E_{22})^2}{E_{22}}$$

$$X^2 = \frac{(105 - 84{,}15)^2}{84{,}15} + \frac{(26 - 46{,}84)^2}{46{,}84} + \frac{(116 - 136{,}84)^2}{136{,}84} + \frac{(97 - 76{,}15)^2}{76{,}15}$$

$$X^2 = 5{,}17 + 9{,}27 + 3{,}17 + 5{,}71$$

$$\mathbf{X^2 = 23{,}32}$$

After calculating X^2, the amount of statistic's freedom degrees was calculated by Equation 5.

$$gl = (amount\ of\ lines\ -1)\ x\ (amount\ of\ columns\ -1)$$

$$gl = (2-1) \cdot (2-1)$$

$$\mathbf{gl = 1}$$

In Figure 4 of critical values of X^2, for a freedom degree ($gl = 1$) and significance level of 0,05 (α = 5%), the critical value of X^2 found was 3,84.

Comparing the calculated value with the tabulated value, it is known that:

calculated value (23,32) > *tabulated value* (3,84)

Thus, it was possible to reject the null hypothesis λ_0 and validate the alternative hypothesis λ_1, according to Equation 14, with a degree of reliability of 95%.

Thus, from the information presented and the result of the test applied, it can be concluded statistically that the capacity of CENIPA to produce final reports in the scope of the military aviation increased after the application of the SFR, confirming the evidence observed in the analysis of Figure 7.

With this finding, it can be verified that the application of the SFR impacted on the 58,86% increase in the production capacity of final military reports produced by CENIPA in the nine first months of the year 2015.

Therefore it can be said that CENIPA increased its capacity to act on the occurrences that form the basis of the Heinrich Triangle and extended the possibilities for identification of contributing factors and latent faults, represented by the Domino and Organizational Accident Theories, respectively.

5 CONCLUSION

The work was conducted to address the following concerns: to what extent has the application of the Simplified Final Report (SFR) impacted CENIPA's capacity to produce final military aviation reports from January to September 2015? In order to answer this research problem and, therefore achieve its general objective, three guiding questions and three specific objectives were elaborated.

Initially documentary research and data collection met the first specific objective (SO1) of identifying the amount of military FR and SFR initiated in each of the established periods. In the AA period 5 accidents, 8 serious incidents and 92 incidents/ground occurrences were recorded, making a total of 105 occurrences. In the AA period 5 accidents, 10 serious incidents and 101 incidents/ground occurrences were recorded, making a total of 116 occurrences. The data obtained were organized by classification of occurrence and presented a distribution consistent with what is advocated by Heinrich's Triangle theory. It was observed that the events of lesser severity were concentrated in the bases of the pyramids of Figures 5 and 6.

The CENIPA database documents were then consulted for the purpose of meeting the second specific objective (SO2), which is to identify the number of FR finalized in the AA period in the field of military aviation. The data obtained accounted for 26 FR finalized in the period.

By means of the documentary consultation to the same database previously mentioned, information was collected in order to meet the third specific objective (SO3) of identifying the amount of SFR finalized in the DA period, in the scope of military aviation. The numbers collected accounted for 97 SFR finalized in the period.

During the study, it was observed that after the application of SFR, the number of finalized investigation processes increased over the period prior to the change. To quantify this increase in the production capacity of final reports, the IIOM indicator was used, which sought the relation between the amount of FR/SFR initiated and the amount of FR/SFR finalized in each period of the research. The comparison between $IIOM_{AA}$ and $IIOM_{DA}$ showed an increase of 58,86% in the production capacity of final reports, after the application of the SFR.

The increase in production capacity was verified by the Chi-Square statistical test, which confirmed the statistical significance of the calculated value and the existence of a correlation between the number of reports completed by CENIPA and the application of the SFR in the scope of military aviation, for the significance level 0,05 (α = 5%).

This estimate has led to the general objective of this research, from which it can be concluded that the application of the SFR impacted the 58,86% increase in the production capacity of final military reports produced by CENIPA in the nine first months of 2015.

By producing a greater number of reports, the possibility of identifying contributing factors and latent failures is increased. In light of the theoretical reference, the contributing factors represent the domino pieces, while the latent faults represent the holes in the slices of the Swiss cheese. The mitigating actions resulting from the final reports represent the removal of a piece from the sequence of dominoes and (or) the obstruction of the holes in the Swiss cheese slices, contributing to the prevention of future accidents.

Thus, the increase in the production capacity of final reports has a direct implication in the prevention of military aviation accidents. This evolution in the speed of the investigation process of the military aeronautical occurrences in the CENIPA implies significant difference in the current context of Brazilian Air Force, with economy of resources and maximization of results.

In addition, the results of this research can help the Aeronautics Command and CENIPA itself in the planning of staffing and distribution within the Center, reducing the consequences of staff turnover.

Finally, this research allows an analysis of the effects of the new adopted report (SFR) and ratifies its use in the investigation of military aeronautical occurrences.

Considering that only the quantitative analysis of the data was approached in this paper, it is suggested that other researches qualitatively investigate the impact of the application of SFR in the investigative processes conducted by CENIPA, in the scope of military aviation.

REFERENCES

AMANCIO, D. B. **O impacto da adoção do Relatório Final Simplificado nos processos Investigativos de Acidentes Aeronáuticos realizados pelo Comando da Aeronáutica**. 2015. 27 f. Trabalho de Conclusão de Curso (Curso de Aperfeiçoamento de Oficiais). Escola de Aperfeiçoamento de Oficiais da Aeronáutica, Universidade da Força Aérea, Rio de Janeiro, 2015.

BRASIL. Lei nº 7.565, de 19 de dezembro de 1986. Dispõe sobre o Código Brasileiro de Aeronáutica. **Diário Oficial [da] República Federativa do Brasil**, Brasília, DF. 1986. Disponível em: <http://www.planalto.gov.br/ccivil_03/Leis/L7565.htm>. Acesso em: 15 ago. 2015.

______. Comando da Aeronáutica. Centro de Investigação e Prevenção de Acidentes Aeronáuticos. Portaria nº 2230/GC3, de 23 de dezembro de 2013. Aprova a reedição da NSCA 3-6, que dispõe sobre a Investigação de Ocorrências Aeronáuticas com Aeronaves Militares. **Boletim do Comando da Aeronáutica**, Brasília, DF, n. 248, 30 dez. 2013.

______.______.______. Portaria nº 166/GC3, de 12 de fevereiro de 2014. Aprova a reedição da NSCA 3-13, que dispõe sobre os Protocolos de Investigação de Ocorrências Aeronáuticas da Aviação Civil conduzidas pelo Estado Brasileiro. **Boletim do Comando da Aeronáutica**, Brasília, DF, n. 34, 18 fev. 2014.

GIL, A. C. **Métodos e técnicas de pesquisa social**. 2. ed. São Paulo: Atlas, 2002.

INTERNATIONAL CIVIL AVIATION ORGANIZATION. **Annex 13, Aircraft Accident and Incident Investigation**.10. ed. Montreal, 2010.

MENDONÇA, F. A. C. A ficha CENIPA 15 e as atividades de prevenção do risco aviário. **Revista Conexão SIPAER**, v. 2, n. 3, 2011.

REASON, J. T. **Managing the Risks of Organizational Accidents**. Aldershot: Ashgate, 1997.

RYAN, T. **Estatística moderna para engenharia**. Campus: Rio de Janeiro, 2009.

SOUZA, R. **Guia Técnico de Ação Inicial de Investigação de Acidentes Aeronáuticos com Aeronaves de Asas Fixas de Acordo com Técnicas Recomendadas Internacionalmente**. 2012. 206 f. Dissertação (Mestrado em Segurança de Aviação e Aeronavegabilidade Continuada)–Programa de Pós-Graduação em Engenharia Aeronáutica e Mecânica, Instituto Tecnológico de Aeronáutica, São José dos Campos, SP, 2012.