REMUNOM
ISSN 2178-6925

Received: 02/09/2026 - **Accepted:** 16/11/2026
Vol: 13.24
DOI: 10.66104/z8kf8b69
Pages: 1-20

PADRÕES DE ACIDENTES COM HELICÓPTEROS NO BRASIL ENTRE 2016 E 2025: ANÁLISE DE CONSEQUÊNCIAS E RECORRÊNCIA

HELICOPTER ACCIDENT PATTERNS IN BRAZIL FROM 2016 TO 2025: ANALYSIS OF CONSEQUENCES AND RECURRENCE

PATRONES DE ACCIDENTES DE HELICÓPTEROS EN BRASIL ENTRE 2016 Y 2025: ANÁLISIS DE CONSECUENCIAS Y RECURRENCIA

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REMUNOM
ISSN 2178-6925

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Resumo

Este trabalho examina os cenários de ocorrências aeronáuticas mais críticos com asas rotativas no cenário brasileiro entre 2016 e 2025, buscando propor uma ordem de priorização exploratória para orientar ações de prevenção em segurança de voo. Amparado por uma abordagem quantitativa e dados primários do CENIPA, o estudo empregou a ordenação por Pareto e a Matriz de Consequência e Recorrência (MCR). Os achados destacam o Voo Controlado contra o Terreno (CFIT) e a Operação a Baixa Altitude (LALT) entre os eventos de maior severidade. Ocorrências ligadas a falhas mecânicas (SCF-PP e SCF-NP) demonstraram participação expressiva, sinalizando possível correlação com fatores operacionais de manutenção. Conclui-se que a mitigação de tais perigos exige uma perspectiva sociotécnica fundamentada na consolidação de Sistemas de Gerenciamento da Segurança Operacional (SGSO) e no aprimoramento dos treinamentos de CRM e MRM nas rotinas de pátio, hangar e cabine de comando.

Palavras-chave: Segurança operacional; Helicópteros; Diagrama de Pareto; Matriz de Consequência e Recorrência; Fatores humanos.

Abstract

This study examines the most critical aeronautical occurrence scenarios involving helicopters in Brazil from 2016 to 2025, aiming to establish an exploratory framework to guide flight-safety mitigation strategies. Grounded in a quantitative approach utilizing official CENIPA data, the investigation incorporated Pareto diagrams and the Consequence and Recurrence Matrix (MCR). The findings identify Controlled Flight Into Terrain (CFIT) and Low Altitude Operation (LALT) as the most critical event types. Mechanical-failure categories (SCF-PP, SCF-NP) also demonstrated significant prevalence, suggesting a potential relationship with maintenance-related operational factors. In conclusion, addressing these operational risks demands a sociotechnical framework through robust Safety Management Systems (SMS) and the enhancement of CRM and MRM training protocols across both cockpit and hangar environments.

Keywords: Operational safety; Helicopters; Pareto diagram; Consequence and recurrence matrix; Human factors.

Resumen

Este estudio examina los escenarios de ocurrencias aeronáuticas más críticos en helicópteros en Brasil entre 2016 y 2025, con el propósito de establecer una jerarquización exploratoria para orientar estrategias de mitigación en seguridad de vuelo. Mediante un enfoque cuantitativo fundamentado en datos del CENIPA, se utilizaron el Diagrama de Pareto y la Matriz de Consecuencia y Recurrencia (MCR). Los resultados sitúan el Vuelo Controlado contra el Terreno (CFIT) y la Operación a Baja Altura (LALT) entre las categorías de mayor criticidad. Las fallas de origen mecánico (SCF-PP, SCF-NP) reflejaron una participación significativa, evidenciando una posible vinculación con factores del ámbito de mantenimiento. Se concluye que la contención de estos riesgos requiere un abordaje sociotécnico basado en la consolidación de Sistemas de Gestión de la Seguridad Operacional (SMS) y la capacitación continua en CRM y MRM en entornos de hangar y cabina.

Palabras clave: Seguridad operacional; Helicópteros; Diagrama de Pareto; Matriz de consecuencia y recurrencia; Factores humanos.

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1. INTRODUCTION

Brazil has an Effective Implementation (EI) index of 95.46% in the Universal Safety Oversight Audit Programme (USOAP), above the global average, demonstrating the alignment of its regulatory system with international civil aviation standards (ICAO, 2025). Nevertheless, CENIPA data for the period from 2012 to 2023 indicate that helicopter accidents have a higher fatality rate than airplane accidents: 61% (130 fatalities in 212 accidents), compared with approximately 40% (544 fatalities in 1,338 accidents) (GUEDES, 2023). This contrast highlights the need for a specific investigation into the operational risk factors affecting rotary-wing aircraft, which is the focus of this study.

The Aeronautical Accident Investigation and Prevention System (SIPAER) classifies accidents based on three areas: the Human Factor, which addresses the medical and psychological aspects of the individual; the Material Factor, which is associated with airworthiness, design, and manufacturing conditions; and the Operational Factor, which concerns human technical performance in operations, maintenance, and infrastructure (BRASIL, 2017). These three investigation areas (Human, Material, and Operational) should not be confused with the “occurrence type” (e.g., LOC-I, CFIT, or SCF-PP), which describes the observed event, nor with the “contributing factor,” defined by CENIPA as a condition whose absence could have reduced the probability or severity of the occurrence.

According to the literature, the Operational Factor has emerged as one of the main causal bases of aviation incidents in the country (ARAUJO *et al*., 2025), based on a sample of 3,635 occurrences/incidents recorded between 2014 and 2023, reflecting the vulnerability of the human element to influences arising from the aviation system (HENRIQUES *et al*., 2019).

Within this context, the present study focuses on helicopters and is guided by two research questions. The first concerns the possible association between the most lethal accidents, understood as those resulting in fatalities or serious bodily injuries among occupants, and operational and human deficiencies, reinforcing the importance of skills such as Crew Resource Management (CRM) (VIEIRA SILVA, 2026), an association explored descriptively in this study rather than through formal

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statistical testing. The second concerns the persistence of mechanical failures as a relevant occurrence type in rotary-wing aircraft, given that studies have reported latent maintenance errors in 14.9% of accidents in the sector (SANTOS; RODRIGUES, 2020; CARDOSO, 2023), an association that is not statistically tested in the present study.

The objective of this article is to map the types of occurrences that present the highest frequency, consequence, and recurrence in helicopter operations in Brazil, providing structured support for the identification of categories that require preventive attention.

2. METHODOLOGY

The methodology adopted in this study consists of a documentary and quantitative analysis of helicopter accidents in Brazil over the past ten years. The investigation combined the Pareto Diagram and the Consequence and Recurrence Matrix to identify the most frequent occurrences and classify their critical factors, as illustrated in Figure 1.

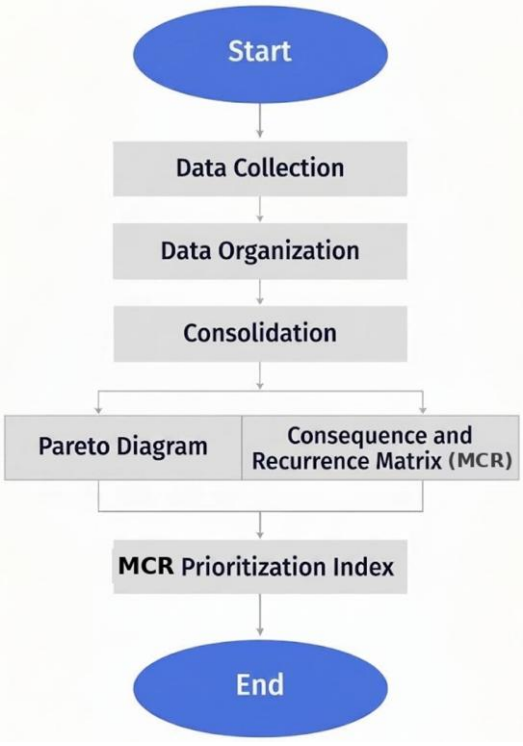

Figure 1 – Methodological flowchart of the research.

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2.1 Data Collection

The data were extracted from the SIPAER panel on March 3, 2026, reflecting the records available in the system as of that date, made available by CENIPA, which allows the consultation and application of different filters related to aeronautical occurrences. The platform enables the selection of records according to criteria such as year of occurrence, month, classification, state, city, aerodrome, and contributing factor. For the development of this research, specific filters were applied, considering the period from 2016 to 2025, the classification “Accident,” and the aircraft type “Helicopter.” Based on these criteria, the records used in the subsequent stages of data analysis were obtained. The dataset used in this study, comprising the accident records extracted from the SIPAER panel, is available upon request to the corresponding author.

For the organization of the database, the principle of stratification was applied (CHIROLI, 2016). Thus, the data were categorized according to different variables, such as occurrence type, contributing factor, and location, with the objective of facilitating the identification of patterns.

2.2 Data Analysis

The extracted data were consolidated into a single table for the sequential application of quality tools. Initially, the Pareto chart ranked the occurrence types by frequency, allowing the identification and prioritization of the main occurrence categories (LÉLIS, 2018).

Next, the Consequence and Recurrence Matrix (MCR) was applied to prioritized occurrences. In this study, the MCR was used as a tool for visualizing and organizing the data to support reflection on the occurrences analyzed and was not considered an objective measure of aeronautical risk or a validated risk assessment model (ABNT, 2021; PMI, 2021). The matrix was structured based on two criteria, evaluated on a scale from 1 to 5: Consequence, represented by the predominant type of injury among the accidents in each category, and Recurrence, represented by the average interval, in days, between accidents in the respective category (ABNT, 2021; INÁCIO *et al*., 2023).

The assignment of scores sought to establish a relative representation among

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REMUNOM
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the categories analyzed, so that higher scores corresponded to greater observed consequences and/or greater recurrence (ABNT, 2021; PMI, 2021). The scales adopted are ordinal in nature, representing increasing levels of consequence and recurrence, without assuming proportionality between the assigned values (Figure 2). Finally, the scores assigned to the two criteria were multiplied, resulting in an MCR Prioritization Index, used exclusively for the organization and comparison of occurrences within the dataset studied and not representing a quantitative measure of risk (CHIROLI, 2016; PMI, 2021).

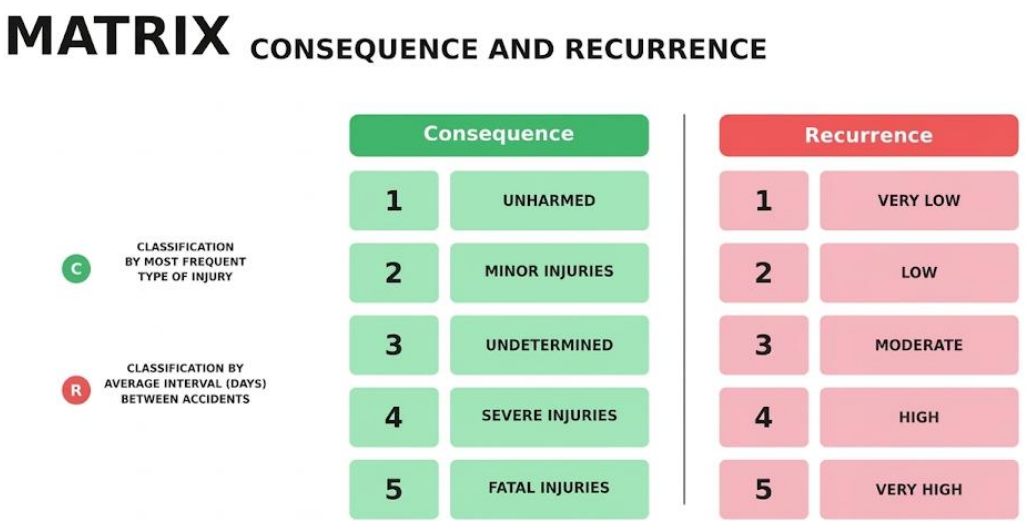

Figure 2 – Matrix for parameterizing the Consequence and Recurrence criteria adapted to the analysis of aeronautical occurrences.

For the classification of accident consequence, the criteria established in the SIPAER Investigation Manual (BRASIL, 2017) were adopted, which classifies damage to the physical integrity of occupants into the following categories:

- Fatal Injuries (5): injuries that result in death within thirty days of the accident;
- Severe Injuries (4): injuries requiring hospitalization for more than 48 hours (beginning within seven days from the date the injury was received); bone fractures (except simple fractures of fingers, toes, or nose); lacerations that cause severe hemorrhage or nerve, muscle, or tendon damage; damage to internal organs; second- or third-degree burns, or any burns affecting more than 5% of the body surface; or confirmed exposure to infectious substances or injurious radiation;

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- Undetermined (3): insufficient information to categorize physical injury;
- Minor Injuries (2): other injuries that do not meet the criteria for fatal or serious injuries;
- Unharmed (1): an individual involved in the aeronautical occurrence who did not sustain any type of injury.

The classification was performed through an individual review of the reports for each accident, considering the information presented in the summary of the respective report, in which the types of injuries sustained by the occupants and, when applicable, the absence of injuries are described.

Recurrence (R) was determined based on the time intervals, in days, between consecutive occurrences of each accident type, considering the arithmetic mean of these intervals over the analyzed period. The cutoff points for the recurrence classes were obtained from the distribution of the mean intervals calculated for each occurrence type, using quintiles to establish five levels of recurrence (ALTMAN; BLAND, 1994). The classification was reversed so that shorter mean intervals, corresponding to a higher frequency of repetition, received higher R values. For categories with only one record during the analyzed period, it was not possible to calculate the mean interval between occurrences. In these cases, the category was classified as having the lowest recurrence for exploratory purposes only.

The thresholds adopted were defined exclusively based on the quintiles of the distribution of the observed mean intervals. No sensitivity analysis was performed using alternative methods for defining the thresholds or different cutoff points. Therefore, the classification of Recurrence levels and, consequently, the final MCR index depend on the thresholds established for this exploratory analysis (Table 1).

Table 1 – Scoring criteria for the Recurrence vector in the MCR.

Criteria	Classification	Value
> 798.33 days	Very Low	1
> 655.37 to 798.33	Low	2
> 268.44 to 655.37	Moderate	3
> 197.30 to 268.44	High	4
≤ 197.30 days	Very High	5

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3. RESULTS AND DISCUSSION

3.1 Geographic Distribution of Accidents

The data extraction identified 167 accidents. Since a single accident can involve multiple events in its sequence, a total of 180 occurrence types were recorded. This study employs two complementary units of analysis: the individual accident (n = 167), used for the geographic distribution and overall accident count, and the occurrence-type code (n = 180), which forms the basis of the Pareto Diagram and the Consequence and Recurrence Matrix (Table 2), since a single accident may receive more than one code. In addition, all investigations of accidents occurring near the end of the analyzed period were considered, even when not yet concluded. The database includes occurrence-type codes registered by CENIPA regardless of the investigation completion status. Contributing-factor data, which typically depend on a concluded investigation, were therefore not used for causal analysis in this study; only the registered occurrence types were analyzed.

Geographic stratification (Figure 3) revealed that the highest incidence of these accidents was concentrated in the states of São Paulo (32), Minas Gerais (28), Paraná (19), and Rio de Janeiro (17), which together account for more than 50% of occurrences in Brazil (Figure 4).

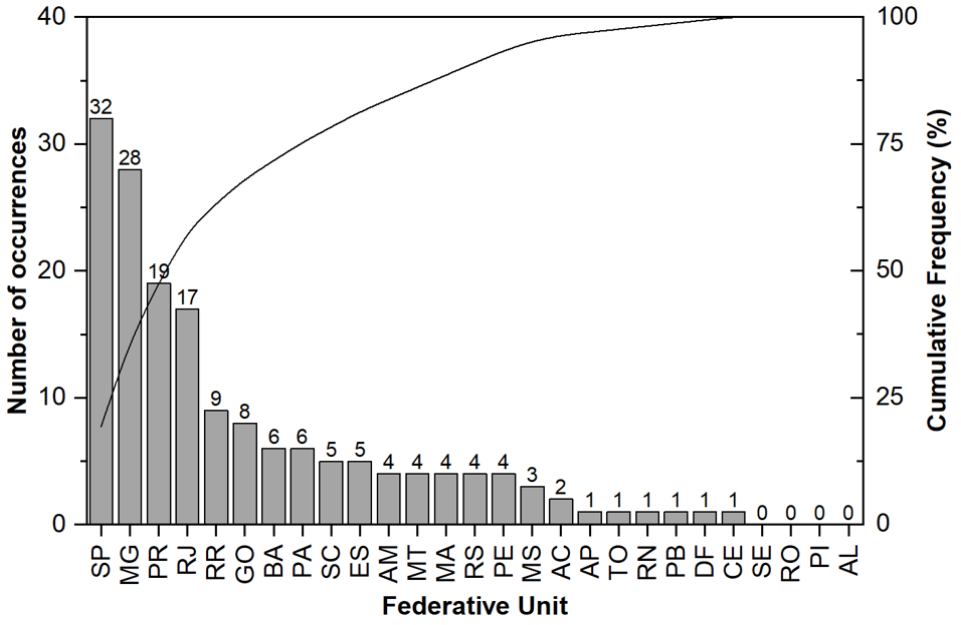

Figure 3 – Distribution of rotorcraft accidents by Brazilian Federative Unit.

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REMUNOM
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Figure 4 – Leading Brazilian Federative Units by number of rotorcraft accidents.

It should be noted that Figure 3 totals 166 accidents rather than 167, since one record appears in the SIPAER panel with the location “NÃO IDENTIFICADA – NÃO IDENTIFICADO – BRASIL” (unidentified). The aircraft departed from Rio de Janeiro and crashed on an offshore platform; therefore, the case was not assigned to any Federative Unit.

The concentration of accidents in these states may be associated with higher fleet density and the intensity of aviation operations in these regions, particularly in executive transport, offshore support, and aeromedical services. This finding suggests that operational risk is not distributed uniformly across the country but is influenced by operational exposure and the specific characteristics of the missions carried out.

It should be noted, however, that the interpretation of these spatial results presents a methodological limitation that goes beyond the scope of individual academic research. Although it was possible to map the absolute geographic distribution of accidents, it is not possible to correlate these data with the actual operational intensity of each state. This is because vital exposure data, such as the detailed volume of flight hours by region, are not made publicly available or stratified

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by state by regulatory or investigative agencies. This scarcity of open data reflects a limitation of the publicly accessible exposure data available for this analysis.

Indeed, although the Air Navigation Management Center (BRASIL, 2026a) publishes the Statistical Yearbook of Air Traffic annually, this document is limited to tracking movement volumes (landings and takeoffs) at a restricted list of the country's 100 primary aerodromes. Consequently, the system fails to account for all local runways, heliports, and private helipads in each state, nor does it convert these flight operations into regionally disaggregated flight hours. Without an integrated database that cross-references occurrences with actual risk exposure, the development of local predictive analyses remains severely limited, preventing the calculation of standardized accident rates by state. Thus, the results presented reflect only the absolute distribution of occurrences and should be interpreted with this caveat in mind, since states with a higher volume of historical records, such as São Paulo and Minas Gerais, may simply reflect a higher density of regional air traffic.

3.2 Main Types of Aviation Occurrences

Figure 5 provides a breakdown by occurrence type, showing that the five main types of occurrences account for approximately two-thirds of all scenarios faced by the affected aircraft.

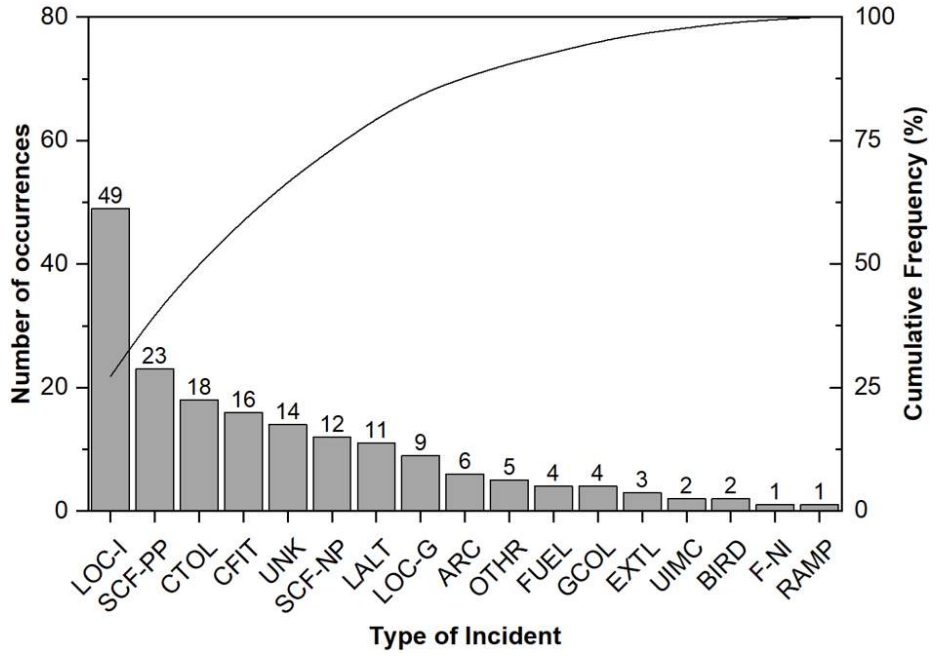

Figure 5 – Pareto diagram of rotorcraft occurrence types.

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A systemic analysis of these occurrences, as evidenced by the quality tools applied, suggests that a significant portion of flight safety vulnerabilities in rotary-wing aircraft in Brazil is associated with human performance. The prominence of events such as Loss of Control in Flight (LOC-I) and Controlled Flight Into Terrain (CFIT) as the most prominent occurrence types is consistent with recent aviation literature. Araujo *et al*. (2025) point to the historical predominance of the Operational Factor in Brazilian investigations, accounting for approximately 96% of the causal basis of occurrences in the country.

The results suggest that events classified as CFIT and LOC-I are predominantly associated with operational factors, consistent with specialized literature (FAA, 2021; IATA, 2025). In rotary-wing aircraft, the occurrence of LOC-I can be exacerbated by characteristics inherent to helicopter flight dynamics, as lift and controllability depend directly on the main and tail rotor systems (LEISHMAN, 2006). Additionally, studies on loss of tail rotor effectiveness (LTE) demonstrate that certain environmental disturbances can rapidly escalate into loss of control in flight (SALEH *et al*., 2022).

Deterioration of situational awareness, poor risk assessment, and complacency in adverse weather conditions are among the main contributing factors to these outcomes. As theorized by Endsley (1995), decision-making in dynamic systems is mediated by the perception of the environment and the projection of future states, with high workload and stress acting as severe constraints on crew cognitive capacity. Given this physiological barrier, there is a heightened need to strengthen Crew Resource Management (CRM) practices, aiming to standardize communication, optimize leadership, and promote technical knowledge sharing in the cockpit to mitigate individual human errors.

The significant representation of the Undetermined (UNK) category in the Pareto Diagram, totaling 14 occurrences and ranking as the fifth most frequent occurrence type during the decade analyzed, requires an essential methodological and theoretical consideration for understanding operational safety. From the regulatory perspective of the Aeronautics Command, the SIPAER Investigation Manual (MCA 3-6) establishes that the UNK classification is technically applied when

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the scarcity of factual data or evidence prevents the precise determination of the causal relationship, also encompassing scenarios in which the aircraft remains missing after the suspension of official search efforts. In addition, as discussed by Araujo *et al*. (2025), the unavailability of detailed information in public databases points to practical challenges that limit the absolute accuracy of retrospective statistical analyses and restrict the primary mapping of occurrences. This UNK classification refers to the occurrence type recorded by CENIPA and differs from the "Undetermined (3)" category used in the consequence scale (Methodology Section); the two concepts should not be confused because they concern distinct variables within the database.

From the perspective of Reliability Engineering and Flight Safety, the absence of a single, identifiable root cause for these indeterminate events correlates directly with the inherently complex and multifactorial nature of aviation accidents. In modern aviation, catastrophic outcomes rarely result from an isolated component failure or a linear human error. Rather, they emerge from an intricate chain of interconnected events in which active operational errors committed on the front lines align with dormant managerial or organizational failures (latent conditions), breaching established safety barriers and defenses. This dynamic sequence aligns with the classic Swiss Cheese Model proposed by Reason (1990).

Thus, when an accident occurs under extreme conditions, involving the total loss of physical evidence due to the severity of the impact, the absence or destruction of flight data recorders, or the death of crew members, identifying a single contributing factor in isolation may become technically more difficult. Therefore, the high number of cases classified as undetermined (UNK) in the CENIPA database should not automatically be interpreted as an absence of a root cause or contributing factors identified by the investigation, but rather as a reflection of investigative limitations in highly complex events, in which the possible destruction of evidence may prevent a reliable reconstruction of the sequence of failures that culminated in the accident.

3.3 Risk Prioritization Using the Consequence and Recurrence Matrix

Finally, Table 2 presents the results of applying the Consequence and Recurrence Matrix.

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Table 2 – Occurrence prioritization using the Consequence and Recurrence Matrix.

Acronym	Description	Nº	C Score	R Score	Result
CFIT	Controlled flight into terrain	16	5	4	20
LALT	Low-altitude operations	11	5	4	20
UNK	Undetermined	14	3	4	12
EXTL	External load occurrence	3	5	2	10
FUEL	Fuel-related	4	5	2	10
OTHR	Other	5	4	2	8
CTOL	Collision with obstacle during takeoff and landing	18	1	5	5
LOC-I	Loss of control in-flight	49	1	5	5
SCF-PP	Engine failure or malfunction	23	1	5	5
UIMC	Unintended IMC	2	5	1	5
RAMP	Ground operations	1	4	1	4
LOC-G	Loss of control on ground	9	1	3	3
SCF-NP	System/component failure or malfunction	12	1	3	3
ARC	Abnormal runway contact	6	1	2	2
BIRD	Birdstrike	2	2	1	2
GCOL	Ground collision	4	2	1	2
F-NI	Fire/smoke (non-impact)	1	1	1	1

Controlled Flight into Terrain (CFIT) and Low Altitude Operation (LALT) presented the highest scores in the MCR, both with 20 points, associated with the predominance of fatal injuries and high temporal recurrence. Although Loss of Control in Flight (LOC-I) presented the highest absolute frequency, with 49 occurrences, its MCR score was 5 points due to the predominance of accidents involving uninjured occupants, despite its high recurrence. This classification represents the predominant consequence observed in the category and does not imply the absence of accidents with more severe consequences.

This result indicates that absolute frequency, when analyzed in isolation, is not sufficient to characterize the relevance of occurrences, since the combination of Consequence and Recurrence makes it possible to distinguish categories with different characteristics within the dataset analyzed.

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3.4 Maintenance as a Component of the Operational Factor: Mechanical Failures and Latent Conditions

Although mechanical failures, categorized as Powerplant Failure or Malfunction (SCF-PP) and System/Component Failure or Malfunction (SCF-NP), have a considerable frequency in the data analyzed using the Pareto Diagram, these occurrence types describe the observed event and do not, in isolation, identify its causal origin, which may be related to maintenance, operation, design, or manufacturing. The literature indicates that a significant proportion of mechanical failures in helicopters may be associated with human errors occurring during maintenance activities. Almeida and Santos (2022) discuss how failures originating in the maintenance environment may act as contributing factors in accidents involving helicopters in Brazil.

Human factors studies applied to aeronautical maintenance indicate that a significant proportion of accidents associated with mechanical failures may be related to operational errors committed by technicians and mechanics, estimated at approximately 80% in certain samples analyzed (CARDOSO, 2023). This percentage refers to the specific sample and period of that study, and its direct applicability to the helicopter accidents analyzed in this article remains to be verified. Human performance limitations, such as chronic fatigue, communication failures during shift changes, and excessive time pressure, may lead to procedures being performed outside prescribed tolerances or to the omission of critical inspection steps. From the perspective of the SHELL Model (Software, Hardware, Environment, Liveware) (HAWKINS, 1987), maintenance technicians do not operate in isolation; they are directly influenced by outdated manuals, inadequate tools, and environmental stress. Such factors generate operational disturbances that compromise repair quality, culminating in an active mechanical failure that may subsequently compromise the airworthiness of the aircraft.

3.5 The Sociotechnical Dynamics and the Swiss Cheese Model

The finding that both the pilot errors and the mechanical failures discussed in the previous sections may derive from weaknesses involving the human element is consistent with the understanding in Reliability Engineering that aeronautical

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accidents are often organizational and multifactorial phenomena. In this sense, the findings of this study may be interpreted in light of the classic Swiss Cheese Model (REASON, 1990), according to which catastrophic occurrences emerge when latent conditions, structural or managerial deficiencies that remain dormant in the system for long periods, become aligned with active errors committed at the operational frontline, as illustrated in Figure 6. This study does not empirically test the model but uses it as an interpretive framework for discussing the results.

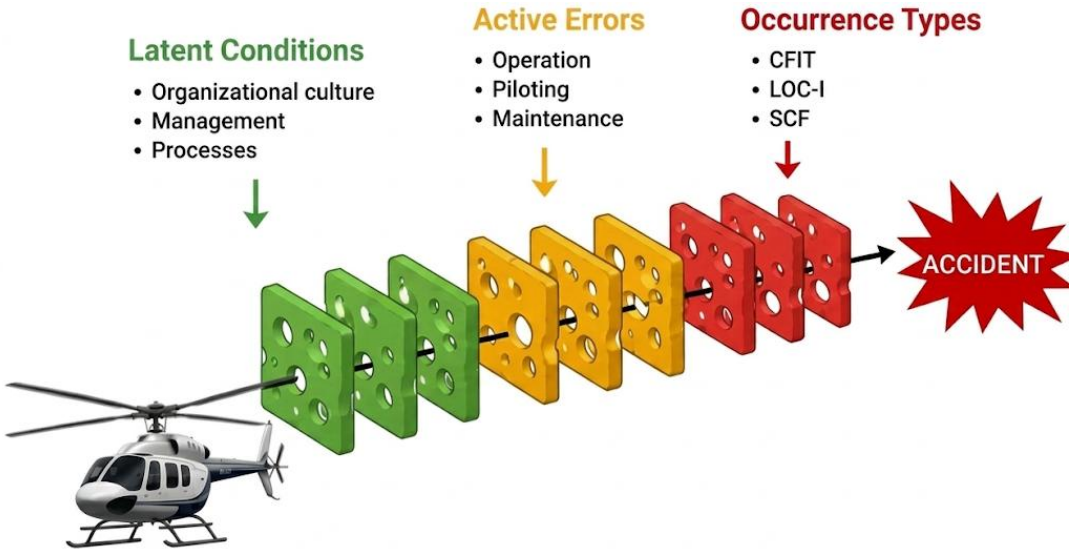

Figure 6 – Swiss Cheese Model.

Thus, the in-flight loss of a tail rotor or a collision with terrain actually represents the alignment of successive breached defensive barriers within the operator's management system.

This approach is complemented by modern flight safety tools that trace the genesis of errors from organizational policies and ineffective supervision down to the preconditions leading to unsafe acts. Aviation is characterized as a complex sociotechnical network in which an occurrence cannot be attributed to an isolated actor, but rather to a compromised interaction among human, machine, and regulatory environments.

Therefore, to ensure effective safety in rotorcraft operations, organizations must consolidate robust Safety Management Systems (SMS) (ANAC, 2012). Mitigating the highest-ranked risks identified in this study requires operators to

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transcend an exclusive focus on material reliability, directing systematic efforts toward maturing safety culture and proactively identifying the latent conditions that concurrently permeate maintenance hangars and flight decks, with improved training in Crew Resource Management (CRM) and Maintenance Resource Management (MRM), in line with current national regulatory guidance (ANAC, 2025a).

3.6 Occurrences Classified as Undetermined

The UNDETERMINED category accounted for 14 accidents during the period analyzed and reached 12 points in the Consequence and Recurrence Matrix (MCR), corresponding to the third-highest score among the categories evaluated. This result is related to the combination of the predominant undetermined classification under the Consequence criterion (Consequence Score = 3) and the high recurrence observed (Recurrence Score = 4). However, beyond its position in the matrix, the presence of undetermined occurrences highlights a relevant limitation for operational safety analysis, since the absence of sufficient information prevents the adequate characterization of the consequences associated with accidents (BRASIL, 2017; BRASIL, 2026b).

The unavailability of information may compromise the identification of patterns and factors associated with occurrences, making it more difficult to understand the circumstances that contributed to their occurrence. In operational safety studies, data quality and the accuracy of records are fundamental elements for previous events to be used in hazard identification and the prevention of new occurrences (ANAC, 2025b; INÁCIO *et al*., 2023). When certain information remains unavailable, the ability to establish relationships between the observed event, its consequences, and possible contributing factors is reduced (ARAUJO *et al*., 2025), limiting the use of these records for the development of effective preventive measures within the framework of Safety Management Systems (SMS) (ANAC, 2012).

In this context, the occurrence of records classified as undetermined also represents a condition of uncertainty for the aeronautical risk management process. The inability to adequately characterize the consequences of an accident makes it difficult to compare it with other occurrences and may limit the identification of relevant trends within the database (INÁCIO *et al*., 2023; BRASIL, 2026b). Thus, the presence

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REMUNOM
ISSN 2178-6925

Received: 02/09/2026 - **Accepted:** 16/11/2026
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of 14 undetermined occurrences during the period analyzed reinforces the importance of the completeness and quality of recorded information, since more consistent data increase the ability to identify hazards, understand events, and direct mitigation measures (ANAC, 2012; CHIROLI, 2016).

It should be emphasized that the UNDETERMINED classification should not be interpreted as an absence of investigation or as evidence of a failure in the investigative process, but as an indication that the information available at the time of the survey was insufficient to establish a conclusive classification of the consequence (BRASIL, 2017). Therefore, the observed result should be understood simultaneously as a characteristic of the analyzed database and as a limitation for interpreting the accidents, highlighting the importance of the availability of reliable information for the continuous improvement of operational safety (GALLEGOS, 2023; LÉLIS, 2018).

4. CONCLUSIONS

This article achieved its objective of analyzing aeronautical occurrences involving helicopters in Brazil over the 2016–2025 period, using official CENIPA data together with quality management tools and descriptive statistics.

In the Consequence and Recurrence Matrix (MCR), Controlled Flight into Terrain (CFIT) and Low Altitude (LALT) presented the highest scores, both with 20 points, followed by the UNDETERMINED category, with 12 points. The presence of occurrences classified as UNDETERMINED also highlights the importance of the availability and quality of information for the adequate characterization of accident consequences.

Regarding occurrences involving mechanical failure (SCF-PP and SCF-NP), a relevant proportion was observed among the types of occurrences analyzed. However, these codes describe the observed event and do not, in isolation, identify its causal factors, which may be related to maintenance, operation, design, or manufacturing. The results obtained, together with the theoretical framework adopted, indicate that human and organizational factors may influence the genesis of these occurrences. The application of the Consequence and Recurrence Matrix

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REMUNOM
ISSN 2178-6925

Received: 02/09/2026 - **Accepted:** 16/11/2026
Vol: 13.24
DOI: 10.66104/z8kf8b69
Pages: 1-20

complemented the analysis of the occurrences by considering the consequence and recurrence characteristics observed throughout the decade studied.

It can therefore be concluded that ensuring the safety of these operations requires going beyond simple mechanical intervention, making it essential to control the organizational factors that precede an accident. The results reinforce that improving operational safety depends directly on the implementation of proactive Safety Management Systems (SMS). It is essential to mitigate latent organizational conditions and strengthen continuous training in human factors, such as Crew Resource Management (CRM) for flight crews and Maintenance Resource Management (MRM) for maintenance teams, strengthening safeguards in both flight deck operations and maintenance routines in hangars.

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ISSN 2178-6925

Received: 02/09/2026 - **Accepted:** 16/11/2026
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