



# HELICOPTER ACCIDENTS IN BRAZIL: AN ANALYSIS OF MAINTENANCE FROM THE PERSPECTIVE OF HUMAN FACTORS

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## Abstract

The helicopter is a very complex machine both in terms of systems and operation. It has a higher accident rate than the fixed wing aviation. Helicopter maintenance is a demanding activity where the personnel involved works sometimes in difficult conditions. There are few studies of maintenance errors in the Brazilian helicopter Air Taxi industry under a Human Factors approach. For this reason, this study was made using the Human Factors Analysis and Classification System-Maintenance Extension (HFACS-ME) to allow a better understanding of the reasons for the occurrence of these events. This study utilized simplified versions of final reports on aeronautical accidents issued by the Center for Investigation and Prevention of Aeronautical Accidents (CENIPA). We employed the HFACS-ME framework to analyze the reports. This involved systematically classifying the reported conclusions according to the established HFACS-ME error categories. The resulting data was then coded and used to generate tables that identified the causal factors contributing to the accidents. This analysis yielded insightful results, supporting the efficacy of HFACS-ME as a tool for uncovering and understanding organizational management issues within the context of these accidents..

**Keywords:** Helicopter Maintenance, HFACS, Human Factors, Accidents, Safety

## 1. Introduction

An helicopter doesn't just appear in the sky. It's the result of a coordinated effort involving various stages, like designing the aircraft itself, putting it through rigorous testing, ensuring proper maintenance, ground handling and personnel training. These are just a few crucial steps that make aviation what it is: a complex socio-technical system. As mentioned in a previous source [1], aviation is a network of interconnected subsystems and components, each playing a vital role.

Historically, given this intricate nature, air accidents were more frequent. However, advancements in technology have significantly improved equipment reliability. In fact, statistics show a steady decline in the proportion of accidents solely caused by technical malfunctions [2].

Despite advancements in technology, human factors still cause a significant portion of aviation accidents, accounting for roughly 60% to 80% today [1]. Two main reasons explain this: 1) The techniques used to investigate mechanical and engineering issues are more sophisticated than those for human factors [3]; 2) The two Boeing 737 MAX accidents, with 346 fatalities caused by a lack of pilot training on a new system, exemplify this challenge [1]. As technology advances, human-machine interaction becomes increasingly complex, demanding new approaches to crew training and adaptation [2].

The complexity of aviation extends beyond the cockpit. Maintenance activities, as highlighted in [4], involve diverse tasks under time constraints, limited feedback, and potentially challenging environments. Furthermore, as commercial fleets age, maintenance workload intensifies. These pressures elevate the risk of human error during aircraft inspections and maintenance.

This research focuses on helicopters for a reason. As pointed out in [5], rotary-wing systems are especially critical. The author emphasizes that helicopters have a much higher fatality rate than commercial airlines, with up to 10 times more deaths per million flight hours.

The study argues that maintenance errors pose a greater risk in helicopters due to several factors: 1) Limited room for error: Transmission and rotor systems have a single point of failure, meaning a single mistake can be catastrophic; 2) Fewer emergency options: Helicopters have a limited range of maneuvers they can perform in an emergency; 3) High impact vulnerability: Helicopters are more susceptible to damage during crashes; 4) Lower occupant survivability: Helicopter crashes often have a lower chance of passenger survival; 5) Frequent maintenance cycles: Helicopter components, especially rotating parts, experience more wear and tear, requiring more frequent maintenance checks which increases the chance of human error.

The literature review revealed a scarcity of Brazilian helicopter accident studies that focus on human factors, particularly those specific to maintenance. To address this gap and strengthen the research, this study coincides with a public consultation launched by the National Civil Aviation Agency (ANAC) to simplify air taxi operations in Brazil, which include helicopters.

Therefore, this study aims to analyze helicopter accidents caused by maintenance activities between 2013 and 2023 using the HFACS-ME method [3, 6]. This analysis will identify the main human factors contributing to maintenance failures in Brazilian helicopter air taxi companies.

## 2. Theoretical Foundations

### 2.1 Literature Review

Different methods exist to understand complex systems involving both technology and human factors, all with the goal of improving safety. A study by [7] compared three such methods - AcciMap, STAMP, and HFACS - by applying them to the same accident. The author found that HFACS, with its pre-defined categories, offered a more robust approach. This is because experts can use it as a consistent framework, and it's particularly useful for analyzing multiple cases to identify common patterns in accident causes.

While some criticize HFACS for being designed specifically for aviation [7], this becomes an advantage in our study. We can explore different approaches within aviation using HFACS, as demonstrated by various studies:

- **Focus on Ground Operations:** One study used HFACS to analyze 87 aviation ground operation accidents reported by investigative agencies worldwide [1].
- **General Aviation in China:** Another study applied HFACS to map human factor causes in 61 general aviation accidents and incidents in China [8].
- **Machine Learning and Accident Prediction:** Researchers used HFACS to categorize 1105 aviation occurrences from the Aviation Safety Network to train algorithms that predict accidents based on human factors [9].
- **Cultural Impact on HFACS:** A study involving 72 Asian airline pilots found that cultural backgrounds might influence how pilots judge accidents using HFACS [10].

Beyond the original HFACS method, there are adaptations that expand its scope. For instance:

- **HFACS-SD:** This variation, proposed by [2], combines HFACS with System Dynamics (SD). The authors analyze F-16 fighter accidents using this method. HFACS first identifies human error risk factors, and then a connected SD model is built using historical data to simulate how these risks evolve over time.
- **HFACS-HE:** This version, suggested by [11], broadens HFACS to include external factors. The author analyzes two helicopter accidents on oil platforms (one in Nigeria and one in the UK) to see how regulations and public policies in each country influenced the accidents. This approach addresses a criticism of HFACS, which is that it doesn't consider broader influences like political factors.

This study is also based on previous research relevant to its focus. Here are some key examples: A More Detailed HFACS-ME: [5] analyzed 58 helicopter accidents in English-speaking countries. They proposed adding a fourth level to HFACS-ME (the version specific to maintenance) to provide a more granular view of human error in maintenance activities. This additional detail can be helpful in developing accident prevention strategies.

Pioneering HFACS Use in Brazil: [12] studied 133 helicopter accidents in Brazil using HFACS, marking the first such study in the country. However, their work had a broader scope, while this study focuses specifically on helicopter maintenance, an unexplored theme in Brazil. Offshore Helicopter Operations: [13] interviewed personnel involved in Brazil's offshore helicopter operations. Their findings on the lack of coordination between pilots and offshore companies offer valuable insights that can be adapted to understand maintenance activities in this study.

## 2.2 HFACS Origins

Seeking to reduce human error in naval aviation accidents, Drs. Douglas Wiegmann and Scott Shappell created HFACS for the Naval Safety Center. This tool helps identify the human factors that contribute to accidents. By understanding these causes, better training programs can be developed to prevent future incidents.

HFACS, as described by [3], categorizes human failures into four levels, mirroring the four levels in Reason's model [3, 14]. These levels are:

- **Unsafe Acts:** Errors made by individuals, like mistakes or failing to follow procedures.
- **Preconditions for Unsafe Acts:** Factors that set the stage for errors, such as fatigue or inadequate resources.
- **Unsafe Supervision:** Errors by those in authority, like approving risky actions or insufficient training.
- **Organizational Influences:** Broader organizational issues that contribute to errors, like poor communication or a weak safety culture.

This approach reinforces the concept that accidents often stem from a combination of human and organizational factors, as highlighted in [14].

## 2.3 HFACS-ME

To address maintenance errors specifically, the Naval Safety Center developed an extension of HFACS called HFACS-ME. This framework, adapted for civil aviation with NASA and FAA collaboration, focuses on analyzing human factors in maintenance activities.

HFACS-ME introduces four key error categories, as shown in Fig. 1:

- **Management Conditions (Latent):** These are underlying organizational issues that contribute to errors, like inadequate procedures or lack of resources for maintenance.
- **Working Conditions (Latent):** Factors in the work environment that increase error risk, such as poor lighting or time pressure.
- **Maintainer Conditions (Latent):** Individual factors affecting the maintainer's ability to perform well, like fatigue or lack of training.
- **Maintainer Acts (Active):** Immediate mistakes made by the maintainer during the work, like forgetting a step or installing a component incorrectly.

By examining these categories, HFACS-ME provides a more comprehensive understanding of the human factors that can lead to maintenance errors.

In their article [15] demonstrated how to frame cases using HFACS-ME. Table 1 shows the classification system.

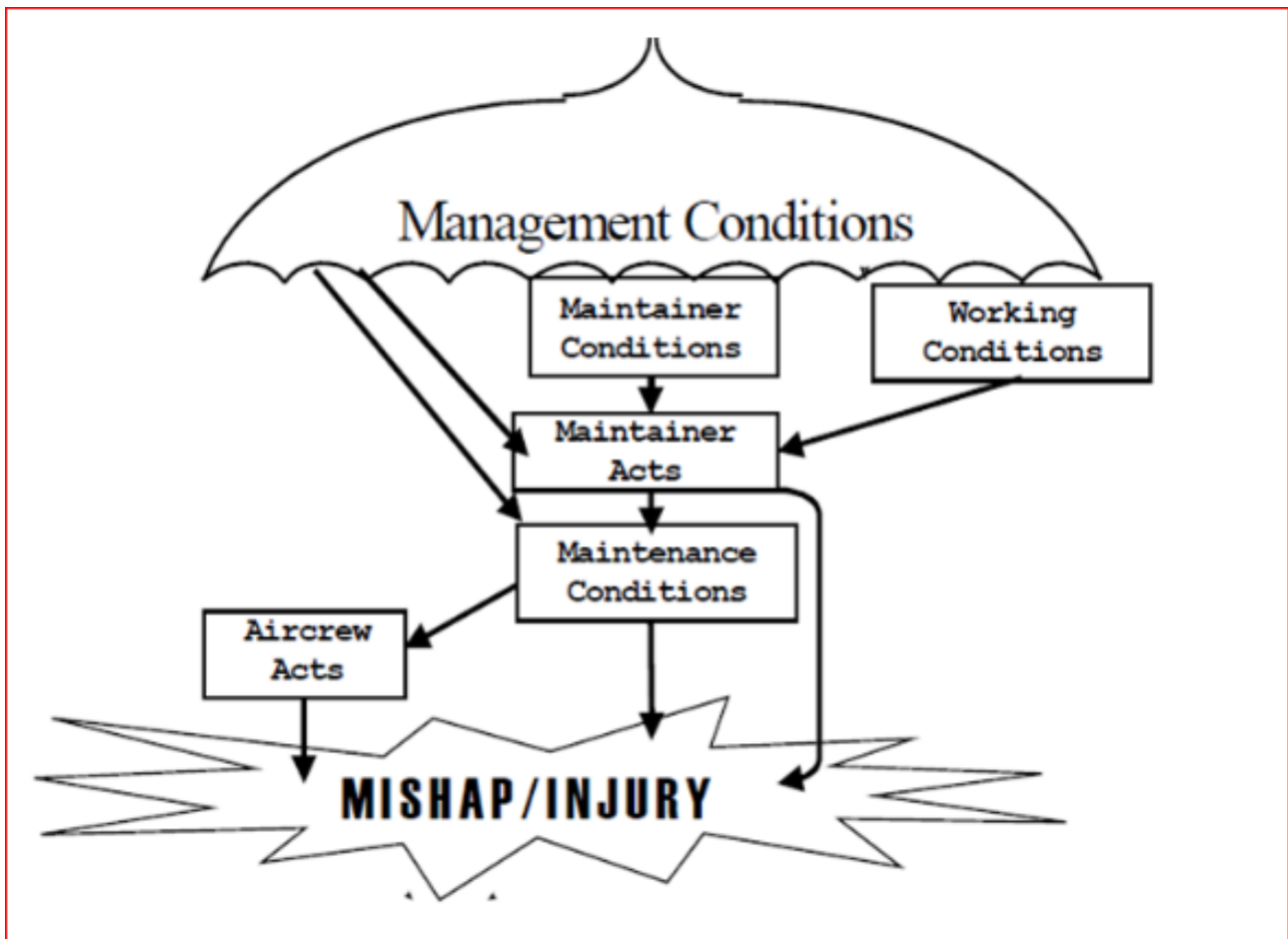


Figure 1 – Error Condition - [15]

### 3. Method

We focus specifically on accidents involving air taxi companies that occurred between 2013 and 2023, where maintenance was identified as a contributing factor.

Data collection involved final accident reports from the Center for Investigation and Prevention of Aeronautical Accidents - (CENIPA), Brazil's aviation accident investigation body, (<https://www2.fab.mil.br/cenipa/index.php/estatisticas>). Focusing on air taxi operations, the selection yielded 16 reports.

One of the authors, which has over 30 years of experience in helicopter maintenance, flight safety, and air taxi operations classified the accidents reports using the HFACS-ME taxonomy. The other authors, with diverse experience in aviation, engineering and occupational safety revised the material and a consensual classification was obtained.

In the following section we present the findings among the 16 reports analysed.

### 4. Results

Prior to presenting our results per se, it is essential to acknowledge the unique challenges associated with helicopter maintenance, as identified by [5] in their study. The author highlights several inherent helicopter characteristics that can contribute to maintenance difficulties:

- Large, moving parts: Helicopters have large components like the main rotor that rotate under significant load during maneuvers.
- Accessibility limitations: The main shaft and rotor hub components are positioned high and compactly within the aircraft, limiting personal reach, handling capabilities, and visibility for activities like reading liquid levels.

Table 1 – ERROR CATEGORIES AND CODING

| First Order           | Second Order      | Third Order                        | Code |
|-----------------------|-------------------|------------------------------------|------|
| Management Conditions | Organizational    | Inapropriate Process               | A100 |
|                       |                   | Inapropriate Documentation         | A101 |
|                       |                   | Inadequate Project                 | A102 |
|                       |                   | Inapropriate Resources             | A103 |
|                       | Supervision       | Inadequate Supervision             | A200 |
|                       |                   | Inapropriate Operations            | A201 |
|                       |                   | Uncorrected Problem                | A202 |
|                       |                   | Supervisory Misconduct             | A203 |
|                       |                   |                                    |      |
| Maintener Conditions  | Physician         | Adverse Mental State               | B100 |
|                       |                   | Physical Condition Adverse         | B101 |
|                       |                   | Physical/ Mental Limitation        | B102 |
|                       | Team Coordination | Inadequate Communication           | B200 |
|                       |                   | Inapropriate Assertiveness         | B201 |
|                       |                   | Inadequate Adaptation/ flexibility | B202 |
|                       | Readiness         | Training/ Preparation              | B300 |
|                       |                   | Certification/ Qualification       | B301 |
|                       |                   | Infraction                         |      |
|                       |                   |                                    |      |
| Working Conditions    | Environrment      | Inadequate lighting/ light         | C100 |
|                       |                   | Climate/ Unsafe Exposure           | C101 |
|                       |                   | Unsafe Environmental Hazards       | C102 |
|                       | Equipment         | Damaged/ Maintenance-free          | C200 |
|                       |                   | Unavailable/ Inadequate            | C201 |
|                       |                   | Obsolete/ Not certified            | C202 |
|                       | Work Area         | Confined                           | C300 |
|                       |                   | Blocked                            | C301 |
|                       |                   | Unaccessible                       | C302 |
|                       | Error             | Attention/ Memory                  | D100 |
|                       |                   | Knowledge/ rule-Based              | D101 |
|                       |                   | Skill/ Technique-Based             | D102 |
|                       |                   | Judgement/ decision-making         | D103 |
|                       | Violation         | Routine                            | D200 |
|                       |                   | Infraction                         | D201 |
|                       |                   | Exceptional                        | D202 |
|                       |                   | Flagrant                           | D203 |
|                       |                   |                                    |      |

- Component complexity: Critical components such as the rotor assembly, engine, transmission, and tail cone are not only difficult to access but also highly complex, further increasing maintenance challenges.

Considering these factors, Fig. 2 depicts the specific systems most frequently involved in the accidents we analyzed.

The results align with the previous study by [5]. Our analysis revealed that approximately 82% of the accidents involved the very systems identified as problematic for maintenance: those with large moving parts, limited accessibility due to cramped spaces, and inherent complexity. This finding reinforces the strong correlation between component accessibility and complexity, and their contribution to maintenance-related accidents.

Looking at Fig. 3, the third order of HFCAS-ME shows that "Inadequate Supervision", Inadequate Processes and Flagrant sum up to 52,7% of causes. It can be seen that this result is different from [5], where "Inadequate Supervision" account for less than 6%, against our result of 23%.

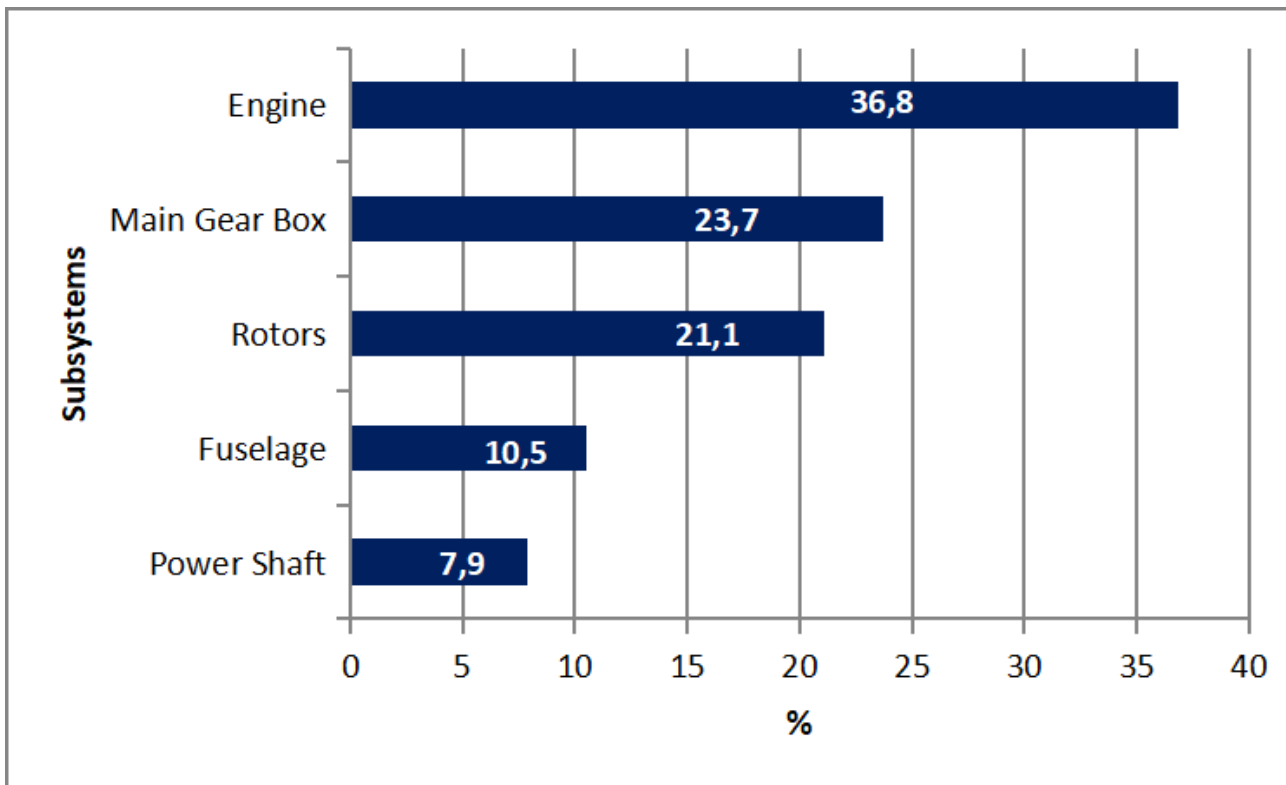


Figure 2 – Accidents by subsystem

In Table 2 we present the complete comparison of this study and the one presented by [5]. An analysis of Table 2 reveals commonalities between our findings and those of [5]. Both studies identify "Inappropriate process," "Inadequate documentation," and "Attention/Memory" as being among the top five contributing factors. However, for the Brazilian accidents, our investigation highlights the additional significance of "Inadequate supervision" (24%) and "Flagrant violations" (13%) as contributing factors.

Table 2 – COMPARISON OF FIRST ORDER HFACS-ME CLASSIFICATION RESULTS

| Ranking | Rashid, 2010 Study                          | This Study               |
|---------|---------------------------------------------|--------------------------|
| 1       | Inadequate Process                          | Inadequate Supervision   |
| 2       | Inadequate documentation                    | Inappropriate process    |
| 3       | Attention/Memory                            | Flagrant                 |
| 4       | Skill/Technique                             | Inadequate documentation |
| 5       | Inadequate design                           | Attention/Memory         |
| 6       | Routine/Norm Violation                      | Uncorrected Problem      |
| 7       | Rule-Based Knowledge/ Error                 | Training/Preparation     |
| 8       | Inadequate Supervision                      | Inadequate resources     |
| 9       | Judgment/Error in Decision Making           | Inappropriate operations |
| 10      | Maintainer's Isolated Infraction/ Violation | Infraction               |
| 11      | Obstructed Workspace                        | Unavailable/Unsuitable   |

Let's delve deeper into the second order of HFACS-ME, as illustrated in Fig. 4.

Fig. 4 reveals that "Supervision" (34%) and "Organizational Factors" (31%) together constitute a significant portion (around 65%) of the contributing factors identified in our analysis. This finding aligns with a similar pattern observed in the study by [13], where "Organizational Factors" accounted for 35% of the causes. However, a key difference lies in the emphasis on "Supervision." While in the

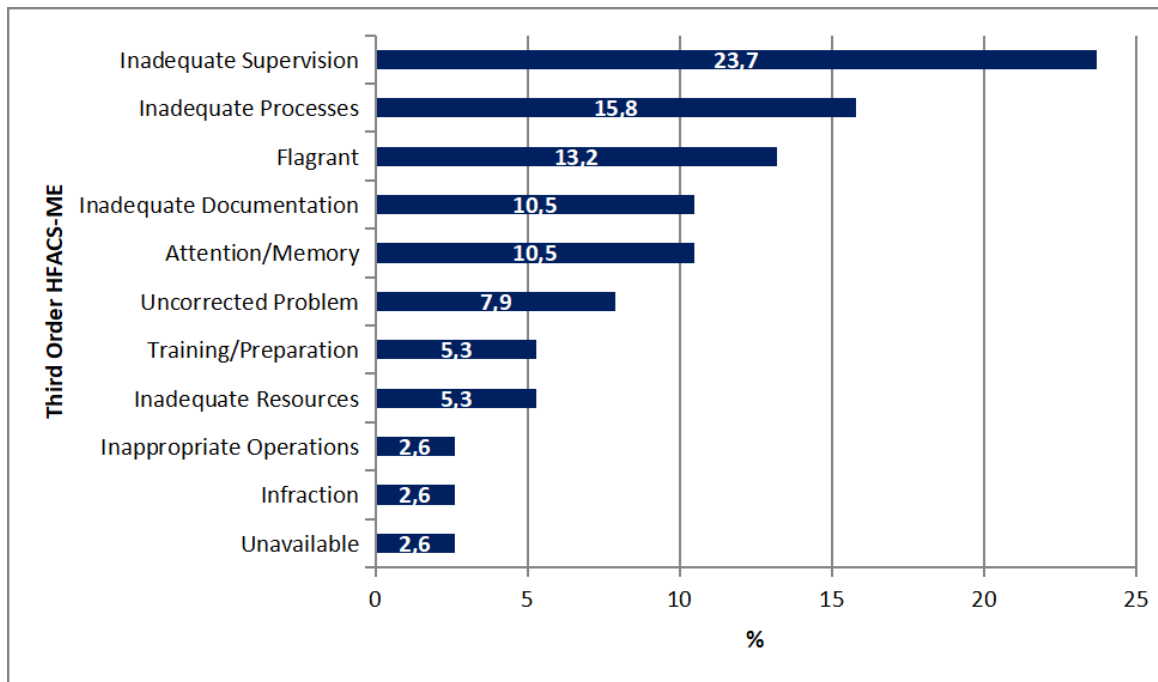


Figure 3 – HFACS-ME Classification - Third Order

[13] study attributed only 10% of the factors to "Supervision," our investigation in Brazil found a much higher percentage (34%).

Furthermore, both studies identified "Violation" as a noteworthy contributor, with our analysis revealing over 15% of the factors related to this category, and [5] reporting a figure close to 12%.

Finally, a discrepancy emerges regarding "Errors" made by maintenance personnel. While [5] identified a high number of errors (around 27%), our analysis in Fig. 4 points to a lower percentage (10%). Despite this difference, it's important to acknowledge that both studies highlight these four factors ("Supervision," "Organizational Factors," "Violation," and "Error") as occupying the top four positions in terms of contributing causes.

Fig. 5 dives into the first order of HFACS-ME, revealing the distribution of contributing factors.

As the Fig. 5 shows, "Management Conditions" (almost 66%) are the most prominent factor group, followed by "Maintainer Acts" (26%). This finding is similar to the study by ([5]), where "Management Conditions" accounted for 44% and "Maintainer Acts" for 41%. Both our investigation and [5] study identified minimal contributions from "Maintainer Conditions" (7% in [5]) and "Working Conditions" (8% in [5]).

## 5. Discussion

### 5.1 Comparison with Other Studies

Our findings can be compared to previous research on accident causes in fixed-wing aircraft by [16, 5]. Table 3 shows that the top five causal factors identified in our study overlap with the first four factors in these other works. This overlap includes both maintainer failures related to "Attention and Memory" and management failures related to "Inadequate Supervision, Process, and Documentation." This suggests a need for interventions that address these latent failures within complex systems.

Another key point is the confirmation of Fig. 2 It shows that the "Motor, Main Transmission Box, and Rotor" subsystems are involved in over 80% of the accidents. These components are difficult to inspect visually due to their complexity and location (e.g., height, rotor blades). This is especially concerning considering the upcoming regulations by ANAC Public Consultation [17], which plan to place fixed-wing and rotary-wing air taxi companies under the same safety standards. As highlighted in the consultation, the unique designs of airplanes and helicopters necessitate distinct safety programs that account for crew and maintainer culture.

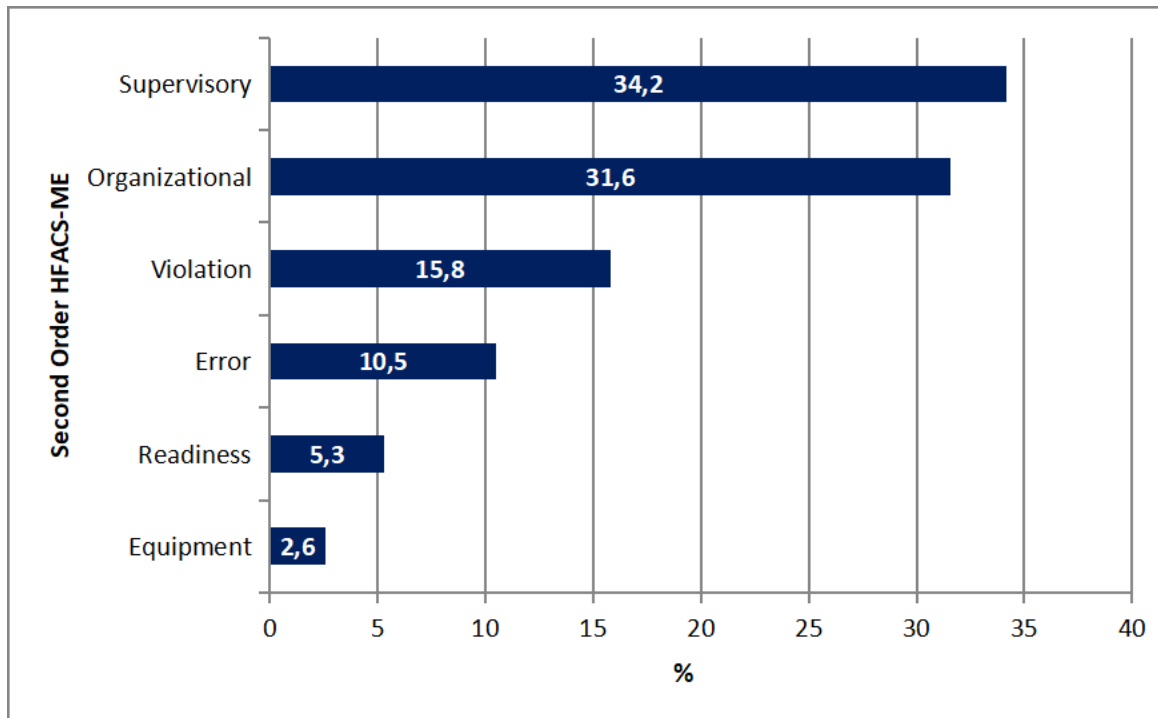


Figure 4 – HFACS-ME Classification - Second Order

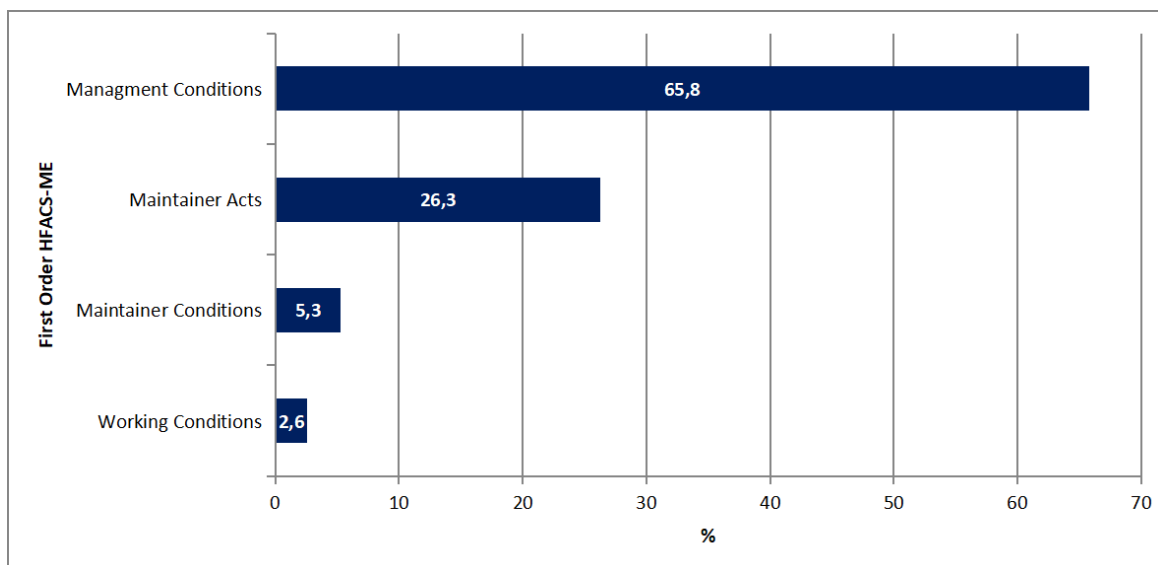


Figure 5 – HFACS-ME Classification - First Order.

Table 3 – COMPARISON OF RESULTS FROM DIFFERENT HFACS-ME STUDIES

| Ranking | Krulak, 2004 [16]                  | Rashid, 2010 [5]                    | This study               |
|---------|------------------------------------|-------------------------------------|--------------------------|
| 1       | Inadequate supervision             | Inadequate process                  | Inadequate supervision   |
| 2       | Judgment/ Error in Decision Making | Inadequate documentation            | Inadequate process       |
| 3       | Attention / Memory                 | Attention / Memory                  | Flagrant                 |
| 4       | Inadequate process                 | Skill / Technique                   | Inadequate documentation |
| 5       | Knowledge/ Rule-based error        | Inadequate design                   | Attention / Memory       |
| 6       | Inappropriate operations           | Routine / Norm Violation            | Uncorrected Problem      |
| 7       | Inadequate documentation           | Knowledge /Rule-based error         | Training/Preparation     |
| 8       | Inadequate communication           | Supervision Inadequate              | Inadequate resources     |
| 9       | -                                  | Judgment / Error in Decision Making | Inappropriate operations |
| 10      | -                                  | Infraction                          | Infraction               |
| 11      | -                                  | Obstructed Workspace                | unavailable/ Unsuitable  |

## 5.2 Human Factors in the Brazilian Context

A Brazilian study by [13] analyzed human factors through questionnaires administered to offshore helicopter pilots. The study identified several key stressors:

- High pressure to maintain constant aircraft availability, placing responsibility for managing failures on pilots.
- Pilot fatigue due to consistently operating at the workload limit.
- Pilot perception that company safety programs are merely paperwork exercises for regulatory compliance.
- Pilot feelings of detachment from the company.

This research is particularly relevant because it captures cultural aspects specific to the Brazilian context, allowing for tailored solutions. While [13] focused on offshore companies, two of the accidents in our study (out of 16) involved air taxi companies servicing offshore locations. This highlights the pressure to maintain availability, pilot fatigue, and the perceived lack of safety culture, all of which can negatively impact the maintenance system (including both processes and personnel).

## 5.3 Addressing Limitations of HFACS-ME

The HFACS-ME method has been criticized for not extending to the political level, as proposed by AcciMap. However, our results suggest a need for interventions at the managerial and organizational levels, not limited solely to crew members or the company. This includes addressing "Inappropriate Documentation," which falls under the responsibility of both manufacturers and regulatory bodies. Finally, it's important to acknowledge the potential biases inherent in any research methodology. As pointed out by [3] and [12], the way research is conducted and the culture of the researchers can influence the focus of the study and potentially overlook certain human factors. Additionally, as noted by [5], the group that developed the HFACS-ME taxonomy may have introduced bias into the categorization of factors.

## 6. Final conclusions

The Key Findings from the HFACS-ME Analysis is that Engine and Main Gear Box as the helicopter subsystems most frequently involved in accidents.

In terms of root causes (using HFACS-ME terminology):

- Third-order factors: "Inadequate Supervision" and "Inappropriate Process" were the most common contributors to accidents.
- Second-order factors: "Supervisory Failures" and "Organizational Issues" were the top two categories. Interestingly, these findings differ from the study by [13] on human factors in aviation.
- For first-order factors (most specific causes), our study found "Management Conditions" followed by "Maintainer Acts" as the most frequent causes.

Overall Conclusion:

Based on these results, applying the HFACS-ME methodology proved to be a valuable tool for identifying and analyzing organizational management problems, particularly in the context of aviation maintenance.

This study's findings and recommendations for future research:

- **Success of HFACS-ME**

Our analysis using HFACS-ME successfully identified and analyzed organizational management problems in airline maintenance. Similar trends across studies suggest common management issues exist in various organizations.

- **Safety Culture and Adaptation:**

Different safety policies for specific projects highlight the need to tailor safety approaches to each operational context while aiming for continuous improvement. The study by [13] underscores the importance of fostering a strong safety culture and employee engagement.

- **Limitations and Future Directions:**

- Limited Scope: The study's focus on a single niche within air operations necessitates broader research across diverse aviation sectors.
- Cultural Influence: Further investigation is needed to understand the impact of cultural factors on maintenance team formation.
- Sample Size: A larger sample size encompassing more representative scenarios is crucial for generalizing the results.
- Regulatory Considerations: ANAC's air taxi regulations emphasize the need to account for the unique aspects of helicopter and airplane operations.

- **Recommendations for Future Research:**

Expand the research scope to encompass various aviation sectors. Analyze the impact of cultural factors on building maintenance teams. Utilize a larger, more representative sample. Investigate alternative methods like AcciMap, Dirty Dozen, HRA, and MEDA. Implement HFACS-ME for all Brazilian aviation incidents and accidents. Explore variations of HFACS-ME, including the 4th Level proposal and external factors integration. Develop a new approach for classifying and validating HFACS-ME factors.

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## References

- [1] Muecklich, N., Sikora, I., Paraskevas, A., and Padhra, A. The role of human factors in aviation ground operation-related accidents/incidents: A human error analysis approach. *Transportation Engineering*, 13, 100184, 2023. <https://doi.org/10.1016/j.treng.2023.100184>
- [2] Wu, Y., Zhang, S., Zhang, X., Lu, Y., and Xiong, Z. Analysis on coupling dynamic effect of human errors in aviation safety. *Accident Analysis and Prevention*, 192, 107277, 2023.
- [3] Wiegmann, Douglas A.; Shapell, Scott A.; *A Human Error Approach to Aviation Accident Analysis The Human Factors Analysis and Classification System*. Farnham, Surrey, England: Ashgate Publishing, 2011
- [4] Latorella, K. A., and Prabhu, P. V. A review of human error in aviation maintenance and inspection. *International Journal of Industrial Ergonomics*, 26(2), 133–161, 2000.
- [5] Rashid, H. S. J., Place, C. S., and Braithwaite, G. R. Helicopter maintenance error analysis: Beyond the third order of the HFACS-ME. *International Journal of Industrial Ergonomics*, 40(6), 636–647, 2010. <https://doi.org/10.1016/j.ergon.2010.04.005>
- [6] Wiegmann, D. A. , and Shappell S. A. A Human Error Analysis of Commercial Aviation Accidents Using the Human Factors Analysis and Classification System (HFACS). *Aviation, Space and Environmental Medicine* Vol 72, NO 11, 2001.
- [7] Salmon, P. M., Cornelissen, M., and Trotter, M. J. Systems-based accident analysis methods: A comparison of Accimap, HFACS, and STAMP. *Safety Science*, 50(4), 1158–1170, 2012. <https://doi.org/10.1016/j.ssci.2011.11.009>
- [8] Wang, W., Wang, J., and Lei, B. General Aviation Accident Masking Causation Based on the HFACS Model Analysis. 2023 *7th International Conference on Transportation Information and Safety (ICTIS)*, 2271–2276, 2023. <https://doi.org/10.1109/ICTIS60134.2023.10243710>
- [9] Nogueira, R. P. R., Melicio, R., Valério, D., and Santos, L. F. F. M. Learning Methods and Predictive Modeling to Identify Failure by Human Factors in the Aviation Industry. *Applied Sciences*, 13(6), 4069, 2023. <https://doi.org/10.3390/app13064069>
- [10] Chan, W., and Li, W.-C. Perception of Causal Factors in Flight Operations Between Ab-Initio and Expatriate Pilots. 2023 *7th International Conference on Transportation Information and Safety (ICTIS)*, 1728–1732, 2023. <https://doi.org/10.1109/ICTIS60134.2023.10243970>
- [11] Omole, H., and Walker, G. Offshore Transport Accident Analysis Using HFACS. *Procedia Manufacturing*, 3, 1264–1272, 2015. <https://doi.org/10.1016/j.promfg.2015.07.270>
- [12] Filho, A. P. G., Souza, C. A., Siqueira, E. L. B., Souza, M. A., and Vasconcelos, T. P. An analysis of helicopter accident reports in Brazil from a human factors perspective. *Reliability Engineering & System Safety*, 183, 39–46, 2019.
- [13] Sant’Anna, D. A. L. M. de, and Hilal, A. V. G. de. The impact of human factors on pilots’ safety behavior in offshore aviation companies: A brazilian case. *Safety Science*, 140, 105272, 2021. <https://doi.org/10.1016/j.ssci.2021.105272>
- [14] Correa, C. R. P., and Cardoso Junior, M. M. Análise e classificação dos fatores humanos nos acidentes industriais. *Produção*, 17(1), 186–198, 2007. <https://doi.org/10.1590/S0103-65132007000100013>
- [15] Schmidt, J., Schmorow, D., and Figlock, R. Human Factors Analysis of Naval Aviation Maintenance Related Mishaps. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 44(22), 775–778, 2000.
- [16] Krulak, D. C. Human factors in maintenance e impact on aircraft mishap frequency and severity. *Aviation, Space, and Environmental Medicine*, 75(5), 2004.
- [17] Agência Nacional de Aviação Civil (ANAC). (2023, October 24). Public consultation for simplification of air taxi operations is open. <https://www.gov.br/anac/pt-br/noticias/2023/aberta-consulta-publica-para-simplificacao-das-operacoes-de-taxi-aereo>.