# Human Factors and Helicopter Accidents: An Analysis Using the Human Factors Analysis and Classification System (HFACS)

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**Abstract.** Due to their maneuverability and operational flexibility, helicopters have become an important alternative means of transport in great metropolitan areas in Brazil in the last decade. Nonetheless, the number of helicopter accidents has increased in parallel. From 2006 to 2015, 211 accidents occurred and 1030 people died. The main aim of this article is to examine the causal factors that lead to the human error in the helicopter accidents which occurred in Brazil between 2006 and 2015 using HFACS. The most frequent HFACS categories were: decision error (68%), skill-based errors (59%), violations (33%), physical environment (15%), issues with inadequate supervision (46%), and organizational processes (15%). By identifying the higher level human errors leading to helicopter accidents, HFACS is useful a tool for accident investigations and accident prevention strategies. The current study provides practical suggestions for top managers for a better helicopter operational safety environment.

**Keywords:** Helicopter accidents · Human error
Human factors analysis and classification system (HFACS)

## 1 Introduction

Traffic jams have increased sharply in the main cities of Brazil over last decade. As a result, due to their maneuverability and operational flexibility, helicopters have become an important alternative means of transport in great metropolitan areas. Here they are used in different scenarios, such as commercial transportation, rescue missions, combating organized crime and military operations. According to the Investigating and Preventing Aviation Accidents Center (IPAAC), Brazil has the fourth largest helicopter fleet in the world. In São Paulo, the largest city in the country, there are 411 registered helicopters. This number is more than twofold higher than in New York City, which has 150. At least four helicopters land or take off in São Paulo every five minutes [1] (IPAAC 2016).

The increase in the use of helicopters might have contributed in parallel to the rise in the number of helicopter accidents in Brazil. According to [1] 211 accidents occurred from 2006 to 2015, when the average number of accidents was 22 per year.


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The highest number of helicopter accidents was in 2011, when 31 accidents happened and lowest was in 2008 with seventeen accidents. As a result, 1030 people died, an average of 103 deaths per year and 63 deaths per hundred accidents. This is a clear indication of the high severity of helicopter accident outcomes. In addition, a helicopter is a type of rotorcraft in which lift and thrust are supplied by rotors. This allows the helicopter to take off and land vertically, to hover, and to fly forward, backward, and laterally, often just with a single pilot. These attributes allow helicopters to be used vin congested or isolated areas where fixed-wing aircraft and many forms of VTOL (Vertical Take-off and Landing) aircraft cannot perform. Therefore, there is a need for detailed analysis of the human errors which occur in helicopter operation.

## 1.1 Human Factor as an Accident Causal Factor

Most studies have focused on underlying human error [2–4] associated with accidents. Human error has been implicated, at least in part, in between 60% and 80% of accidents in many safety-critical domains, including civil aviation [5]. Nevertheless, it is generally accepted by accident investigators in the field that aviation accidents are the result of a chain of events culminating with the unsafe acts of operators (e.g. crew) [6–8]. According to findings from these studies, efforts to understand the casual factor which lead to human error in a civil aviation accident must be made, in order to reduce the frequency and, consequently, to reduce the number of accident from current levels. Nonetheless, human error is much more complex and elusive, making it difficult to apply any sort of investigative method that is both easily understood and universally accepted. Without a structured and standardized classification scheme, one is left with little more than narrative summaries of the event, making it virtually impossible to quantify and trend specific types of human error either within or across aviation domains [8].

Currently, human factors approach to system safety have been used to understand the causes of accidents and can be applied to the helicopter accident context. These models of human error in organizational systems take a systems approach, noting that accidents can be attributed to a combination of active operator-level errors and inadequate or latent conditions that reside throughout the system [9, 10]. Such models have underpinned the development of several methods of accident investigation and analysis that use error and latent condition classification schemes to provide an analysis of the types of failure involved in accidents [11]. One of the most widely used approaches is Human Factors Analysis and Classification System (HFACS) [4] which has featured in the accident analysis in many publications [12, 13] and is described in Sect. 1.3.

## 1.2 Motives and Aims

There are studies which use HFACS to analyze accident data in different domains, such as mining [11, 14]; railways [15, 16]; civil aviation [6, 17–19]; Healthcare [20] and helicopter maintenance [21], in which the contributing factors reported are categorized into HFACS category, then they are analyzed. Nonetheless, studies to analyze helicopter accidents data in particular using HFACS have not been found in peer-reviewed journal. [22] investigated human error in helicopter accidents in Taiwan using HFACS, yet their work has not been published in a peer-reviewed journal. This may be due to the fact that research into human error accident analysis in aviation has focused on civil aviation in general, not on helicopters in particular, and military aircraft. Filling this important gap in the current literature has motived the present study.

In Brazil, helicopter accident investigations are carried out by Investigating and Preventing Aviation Accidents Center (IPAAC), which is under the authority of the Aeronautical Ministry of Brazil. The actual human factors approach used in accident investigation by the IPAAC [1] does not use any specific human error theoretical framework. As a result, the trend of specific types of human error either within or across aviation domains is not quantified and nor determined. Furthermore, there are no studies on causal factors which lead to human error in helicopter accidents in the country. Therefore, the main aim of this study is to know and understand the causal factors leading to human errors in helicopter accidents which happened in Brazil between 2006 and 2015 by using HFACS. Secondly, to statistically examine the presence of relationships between failure and error categories across the levels of the HFACS to ascertain the extent to which failure pathways might be common across aviation industries. Thirdly, it is to propose recommendations based on these causal factors. The ultimate objective of this article is to contribute to the improvement of helicopter transportation safety in Brazil and in the world as a whole. In the long term, this may contribute to preventing recurrences of helicopter accidents.

### 1.3 Human Factors Analysis and Classification System (HFACS)

The Human Factors Analysis and Classification System (HFACS) is a taxonomic incident coding system developed for the US Marine Corps aviation sector for application by practitioners to aid in investigating and analyzing the role of human factors in accidents and incidents [23]. HFACS provides analysts with taxonomies of failure modes across the following four levels [8]. The first of four levels of the HFACS (working backward from a crash) describe the unsafe acts committed by operators that led to the crash, classified into two categories of errors and violations. Level 2 factors, preconditions for unsafe acts, refers to both active and underlying latent conditions that contribute to the occurrence of unsafe acts. Preconditions for unsafe acts comprise three categories: conditions of operators, environmental factors, and personnel factors. The third level of failure within HFACS, unsafe supervision, considers those instances where supervision is either lacking or inappropriate. The final category of failure, organizational influences, addresses the fallible decisions made at board and management levels that influence operations at the lower system levels [7].

Additionally, based on the taxonomies presented by HFACS, which work backward from the immediate causal factors, the analysts classify the errors and associated causal factors involved an accident [7]. Therefore, the HFACS framework goes beyond the simple identification of what an operator did wrong to provide a clear understanding of the reasons why the error occurred in the first place. In this way, errors are viewed as consequences of system failures, and/or symptoms of deeper systemic problems, not simply the fault of the employee working at the "pointy end of the spear" [14]. Furthermore, the HFACS framework is capable of exploring the possible causes of accidents with different complexities. In recent years, the HFACS framework has been widely introduced into civil aviation and other domains to study human errors in accidents because of its high reliability [3, 24].

# 2 Method

## 2.1 Data Source

The accident reports used in this analysis were obtained from databases maintained by Investigating and Preventing Aviation Accidents Center (IPAAC). Data on a total of 165 cases, which occurred between January 2006 and December 2015, were obtained [1]. This was the entire population of cases for which investigation final reports were available. Nonetheless, some those reports have contributing factors identified, yet they were not described in detail. Only final reports in which contributing factors were identified and described were included in this study. A total of 133 final accident reports were submitted to further analysis.

## 2.2 Coding Process

Four analysts coded each incident/accident case. The analysts had previously been trained together on the use of the analysis and categorization framework to ensure that they achieved a detailed and accurate understanding of it. This training consisted of seven half-day modules delivered by a human factor expert. The training syllabus included an introduction to the HFACS framework; explanation of the definitions of the four different levels of HFACS; and a further detailed description of the content of the eighteen individual HFACS categories.

Given the high inter-rater reliability found in previous HFACS analyses (e.g. [5, 6, 11, 16, 22, 23], consensus classification was deemed appropriate for analysis. That is, the group as a whole, including the human factor expert, discussed each case and classified the identified human factors within the HFACS framework. The presence or absence of each HFACS category was evaluated from the narrative, sequence of events, findings, and conclusion. Each HFACS category was counted a maximum of one time per each incident/accident case.

## 2.3 Statistical Analysis

Preliminary assessments of the incident characteristics and HFACS data were performed using frequency counts. The nature of the relations, if any, between each HFACS level with the level immediately above was conducted using Chi-square Test ($\chi^2$). The lower level categories in the HFACS were designated as being dependent upon the categories at the immediately higher level in the framework, which is congruent with the framework's underlying theoretical assumptions. From a theoretical standpoint, lower levels in the HFACS cannot adversely affect higher levels. Higher levels in the HFACS are deemed to influence (cause) changes at the lower organizational levels, thus going beyond what may be deemed a simple test of co-occurrence between categories. Finally, Odds are calculated for lower-level factors, the odds being the ratio of the probability that a (lower-level) factor is present, to the probability that it is absent. The odds can be calculated under two conditions: one for when a higher-level factor is present, and another for when a higher-level factor is absent. Analyses were conducted using the software Statistical Package for the Social Sciences (SPSS).

# 3 Finds

## 3.1 Overall Results

As can be seen in Table 1, the majority of causal factors involved pilots and the environment. Unsafe acts were identified in more than three-quarter (81.2%) of the cases. Preconditions for unsafe acts were associated with 37.6% of the cases, whereas unsafe supervision was identified in 48.9% of the cases. Organizational influences were identified in relatively few cases (18%).

**Table 1.** Frequency and percentage of HFACS codes identified in helicopter accidents

| HFACS Category | Frequency | Percentage |
|---|---|---|
| **Level-1 Unsafe acts** | **108** | **81.2** |
| Decision errors | 90 | 67.7 |
| Skill-based errors | 79 | 59.4 |
| Perceptual errors | 9 | 6.8 |
| Routine violations | 44 | 33.1 |
| Exceptional violations | 0 | 0.00 |
| **Level-2 Preconditions for unsafe acts** | **50** | **37.6** |
| Physical environment | 20 | 15.0 |
| Technological environment | 19 | 14.3 |
| Adverse mental states | 9 | 6.8 |
| Adverse physiological states | 0 | 0.0 |
| Physical/mental states | 0 | 0.0 |
| Crew resource management | 12 | 9.0 |
| Personal readiness | 0 | 0.0 |
| **Level-3 Unsafe supervision** | **65** | **48.9** |
| Inadequate supervision | 61 | 45.9 |
| Planned inappropriate operations | 15 | 11.3 |
| Failed to correct problem known | 0 | 0.0 |
| Supervisory violations | 2 | 1.5 |
| **Level-4 Organizational influences** | **24** | **18.0** |
| Resource management | 0 | 0.0 |
| Organizational process | 20 | 15.0 |
| Organizational climate | 8 | 6.0 |

The most frequent unsafe acts were decision error (67.7%), skill-based errors (59.4%) and violations (33.1%). Decision error commonly involved was "*wrong make* *decision*" of pilot (e.g. to abort a landing or take off). The most common type of Skill-based errors was "*inadequate application of controls*", whereas violations were typically related to failure to follow organizational procedures (e.g. intentionally ignoring standard operating procedures, neglecting standard operating procedures, applying improper standard operating procedures and diverting from standard operating procedures).

The preconditions most commonly involved were the physical environment (15%), which typically involving "*adverse weather condition*" (e.g. poor visibility caused by fog and rain), and the technological environment (14.3%) commonly involved "*poor infrastructure*" (e.g. precarious helipad). Crew resource management was present in 9.0% of accidents, which involved mostly "*poor crew coordination*", whereas adverse mental states (e.g. anxiety and impulsiveness of pilot) were identified in 6.8%. Other preconditions for unsafe acts, such as adverse physical states and physical or mental limitations, were not identified.

The unsafe supervision failures included inadequate supervision (45.9%), which commonly involved "*oversight of personnel and resources*" (e.g. oversight of maintenance services, lack of training to crew), planned inappropriate operations (11.3%) (e.g. assignment of inexperienced crew), and supervision violation (1.5%) (e.g. supervisor determine flight hour was not recorded). Failure to correct a known problem was not identified. Finally, the organizational influences included organizational process (15%), which mostly involved "*lack of procedure to guide the pilot under critical flight condition*", and organizational climate (6.0%), in which "*work group culture*" (e.g. culture based on informal procedure) was the most frequent. Resource management was not identified.

## 4 Conclusion

The data in this study support the comprehensiveness of HFACS for these helicopter accidents in which all error types were classified. Although it is not perfect and approaches such as HFACS are entirely dependent upon the quality of the data provided and the analysts involved [2, 23, 25], it can be used to reliably identify the underlying human factors problems associated with specifically helicopter accidents. Albeit some of the findings in this study may come as no surprise, they provide data where only assumption existed based on previously civil aviation accidents studies. Furthermore, they provide additional information for the development, implementation, and quantifiable assessment of putative intervention and mitigation strategies in helicopter industry, particularly in Brazil.

By using a structured framework to identify human factors, results from this study can be compared to other industries as well. This comparison may enable safety interventions that proved successful in civil aviation to be transferred and increase cross domain information sharing. After all, if an intervention has been proven successful in one industry, lessons can be learned by safety professionals in other industries. When was compared with earlier studies, our analysis of the statistical associations between the categories at different levels is in line with those found in similar HFACS analyses undertaken in other civil aviation studies (e.g., [5, 22, 26]) although the frequencies do not present a pattern of similarity or difference with them.

Finally, it is important to say that neither HFACS nor any other error-analysis tool can correct the problems once they have been identified. Such corrections can only be derived by those organizations, government, practitioners and human factors professionals who are dedicated to improving aviation safety.

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