HELICOPTER ACCIDENTS: DATA-MINING THE NTSB DATABASE

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Key words: accident analysis, helicopter fatality, safety, weather

Abstract. Large-scale accident analyses have combined airplane and helicopter accidents or have ignored the rotary-wing aircraft altogether. An overview of all helicopter accidents of the last twenty-five years in the United States allows comparisons with other types of aircraft and provides a basis for comparing specific helicopter operations to helicopter flights in general. A first analysis of the data provided by the NTSB, the American organization that collects these accidents, shows that helicopters are significantly more likely to be in a fatal accident when the accident occurred in adverse weather or IMC conditions, or when the accident involved a collision with an object in flight. In contrast, accidents in which the helicopter was near to the ground show significantly fewer fatalities. Also, specialized helicopter operations, such as instruction flights and aerial applications, have significantly fewer fatalities than business and personal flights. The specificity of helicopter operations require that further research is needed on the causes and contributing factors of specific operations in relation to the general findings presented in this study.

1. INTRODUCTION TO THE NTSB DATABASE

The National Transportation Safety Board (NTSB) of the United States investigates aviation and other transport related accidents. Their standardized reports are published on a publicly accessible internet database to which they add regular general analyses. The NTSB database is unique in its size, uniformity and public access.

The NTSB database is a collection of all accidents with aircraft that have taken place in the United States or that occurred abroad with an aircraft holding an American registration. The number of reported accidents since 1982 exceeds 80,000 cases. NTSB investigators make up a standardized report that consists of a factual report and a probable cause statement. In most cases, the factual consists of a minimum of five pages and a probable cause of two pages. The number of pages varies depending on the size of the aircraft and the extent of the investigation that was conducted. Fatal accidents, in nearly all cases, include a report by a medical examiner and usually have a more extensive text. If the investigation is not yet completed, the NTSB may publish a preliminary report indicating its first findings.

The NTSB has published most accident reports from the 1960s onwards and nearly all reports from the 1980s onwards are available in a consistent format. This allows studies over extensive time periods but most of all it facilitates the comparison of accidents or groups of accidents.

The accidents are categorized according to an elaborate classification system that encodes nearly all elements present in a NTSB report. These elements include characteristics of the aircraft, weather conditions, facts about the occupants including the experience of the pilot, the type of operation, the circumstances of the flight as well as the elements of the analysis that follow in the probable cause statements. Although some categories are crude and not all elements can be present, it allows a wide range of possibilities for data-mining and statistical analysis.

Apart from the United States, there are few countries with a similar density of aircraft. More importantly, most countries are not consistent with their accident investigations and even fewer make their reports publicly available on this scale. So far, the United States provides the only database that features such a number and consistency of data.

1.1 Occurrences, factors, causes and the definition of accidents

An accident is defined by the NTSB as an instance in which the aircraft was substantially damaged or destroyed, or in which one of the occupants was severely or fatally wounded. A fatality is then defined if the occupant died within thirty days of the injuries sustained during the accident. Incidents include all other cases in which only minor damage or injury was sustained. Although the NTSB database includes some incident reports, the Federal Aviation Authorities (FAA) in the United States is responsible for collecting incident reports as well as voluntary reports on near accidents.

The analysis of aviation accidents is published as a probable cause statement and commonly includes one or more occurrences, factors and causes pertaining to the accident. An occurrence is a happening that preceded the damage to the aircraft or the injury to the occupant. The cause of this occurrence is then determined by the investigator who may identify additional factors that did not cause but contributed to the accident in question. An accident may have a series of occurrences and it may have more than one cause or factor per occurrence depending on the situation. In addition, there are findings that are determined by the investigator, which are commonly summarized in a few sentences at the end of the probably cause statement.

The codes for these elements of the probably cause statements have been used to determine, for instance, the most frequent cause of helicopter accidents or the number of fatal accidents within a particular operation.

1.2 The limitations of the NTSB database

Despite the detail, size and uniformity of the accident reports in the NTSB database, an analysis of these accidents is limited.

Firstly, the accuracy of the database depends on the competence of the investigators. This includes the problem of possible errors, omissions, exaggerations or problematic conclusions in the reports but, more importantly, the simple fact that the most quoted part of each report, the probable cause, is a matter of interpretation.

Then there is, in the case of helicopters, a relatively high number of 367 accidents for which the cause of an occurrence was undetermined. Out of these 367 accidents 251 (68%) reported an engine failure. These accidents were not more likely or less likely to be fatal than others, but they indicate that even after an investigation there is not always a primary cause of the accident. The high rate of engine failures in this sample suggests that the cause of engine failures cannot always be determined by way of a NTSB investigation.

The diversity of climates, seasons, aircraft, operations, experience of the pilot and a host of other variables makes a conclusion of the data complicated. The diversity of items that are not even reported, such as psychological characteristics of the pilot, further weaken any generalization.

Lastly, for the purposes of this study, an analysis of the NTSB database cannot be generalized to other countries or even to future time periods without addressing, for instance, changes in regulation, aviation practices and developments in aviation technology.

1.3 Individual operations versus aircraft specific research

When a specific sample is taken, such as the total of helicopter accidents, the limitations of studying the NTSB database are more specific. Helicopter operations are particularly diverse and, therefore, cannot be lumped together unconditionally in a single study. Also, helicopter flights are more diverse in their number of flight phases. This is hardly compensated by the consistently low number of passengers and low weight of the aircraft compared to those of airliners, or the defining presence of a rotor system.

The long list of limitations is important for understanding the possible use of the data analysis presented below. The main purpose of this study is to provide a reference for future helicopter accident analyses. The general characteristics of helicopter accidents and the significant relations between them, which are presented here to a limited extent, provide such a basis.

2. DATA-MINING RESEARCH

The data were extracted from the NTSB online database and converted to a database program for further analysis. [1] The first results of this research are presented here by way of descriptive statistics. Possible significant relations between datasets were determined using Pearson's χ^2 -analysis. Relations were defined significant if *p*-values were below 0.05.

2.1 Results

Between 1982 and 2006, the NTSB recorded a total of 4,863 accidents with helicopters in which 1,229 helicopters were destroyed, 3,583 were substantially damaged with 18 reporting only minor damage and 33 no damage at all. This results in an average of about 194.5 accidents per year with a range between 108 and 277 accidents per year.

A fatality was reported in 741 cases, which means that 15.2% of all helicopter accidents were fatal. In most cases, 2,328, no injury was reported, in another 598 accidents at least one of the occupants had serious injuries and in the remaining 920 cases only minor injuries were sustained.

From 1990 up until 2005, the Federal Aviation Administration of the United States provides estimates of the total hours flown by aircraft type. Compared to the number of hours flown per year, the risk of having a helicopter accident is between 11.6 (1994) and 6.3 (2005) accidents per 100,000 flight hours. [2] When excluding 2006, the first twelve years of the time period between 1982 and 2006 had 327 more accidents reported than the latter twelve years of this study, suggesting a downward trend that is also visible in the accident rate per hour flown.

California (778), Texas (377) and Florida (363) reported the highest number of accidents. This is consistent with the high number of flight movements reported for these states in general aviation and commuter/air taxi operations [3]. The percentage of fatal accidents ranges between 0 % for North Dakota, which had 26 non-fatal crashes in total, or Wyoming with a total of 48 crashes that were all non-fatal; and percentages of 25% and above with, for instance, Wisconsin reporting 11 out of 43 accidents as fatal, and Tennessee with 9 fatal accidents out of 34. Both Tennessee and North Dakota are also mentioned in other studies for, respectively, their high and low accident rates in aviation. [3]

Accidents were evenly distributed over the week with the lowest number of 567 on Sunday and the highest of 782 on Saturday. The lowest relative number of fatalities was found on Monday (13.4%) and the highest on Tuesday (20.3%).

2.2 Fatality

Adverse weather and visual conditions appear more often in fatal accidents than in non-fatal ones. Helicopter accidents were 3.0 times more likely to be fatal when conducted in night conditions ($\chi^2 = 95.04$, $p < 0.001$, df = 1), i.e. in conditions in which light was reported as a finding or contributing factor. Accidents are 6.3 times more likely to be fatal in IMC conditions ($\chi^2 = 199{,}97$, $p < 0.001$, df = 1). The occurrence of an in-flight encounter with weather had a similar negative effect leading to accidents that were 5.6 times more likely to have a fatality

($\chi^2 = 145{,}99$, $p < 0.001$, $df = 1$) than accidents without this occurrence. Just weather conditions reported as a contributing factor in the accident already increased the risk of a fatality by a factor 1.8 ($\chi^2 = 31.82$, $p < 0.01$, $df = 1$).

In contrast, accidents that occurred near the ground are less likely to be fatal. Rollovers made it 6.2 times less likely that the accident was fatal. In situations where an autorotation was a contributing factor to the accident; it also had significantly fewer fatalities with an odds ratio of 2.8 ($\chi^2 = 8.69$, $p < 0.01$, $df = 1$). When the cause of the accident was the flare, the odds were reduced by a ratio of 7.3 that the accident was fatal ($\chi^2 = 31{,}17$, $p < 0.001$, $df = 1$). The occurrence of a loss of engine power, mechanical or non-mechanical and partial or total, also reduced the odds. In particular a total non-mechanical loss of engine power reduced the odds of a fatality by 2.5 ($\chi^2 = 20.29$, $p < 0.001$, $df = 1$).

These results on weather and light conditions largely confirm earlier studies on general aviation and specific helicopter operations [4]. Also, accidents, such as mid-air collisions, occurring at lower altitudes have shown to be less fatal than those at higher altitudes [5], supporting the idea that roll-overs and autorotations that have or bring the aircraft to a lower altitude are less likely to be fatal.

A second group increases fatality due to collision. In situations where clearance is the cause of the accident or when there is an in-flight collision with an object or an object on the ground, they all significantly increase the odds for a fatal versus a nonfatal accident. These accidents commonly have additional occurrences, such as weather or darkness, that already increased the likelihood of a fatality.

Other occurrences are also significantly related to fatality and the largest categories include 'loss-of-control-in-flight' and 'in-flight collision with terrain' both of which often co-occur with other causes and do not always allow a useful interpretation. Loss-of-control-in-flight is a rest category for occurrences that do not readily fit another category. It is the highest initial occurrence with 794 cases of which 108 were fatal. In-flight collision with terrain/water leads to an odds ratio of 4.2 ($\chi^2 = 302.59$, $p < 001$, $df = 1$) in likelihood for a fatality. It involves 1,914 accidents as opposed to, for instance, 222 flights in IMC conditions. This in-flight collision with terrain is the initial occurrence in only 335 cases of which 64 were fatal, while more than half of the flights conducted in IMC conditions were fatal.

2.3 Specific operations

Research on helicopter accidents requires a specification for each operation. The diversity of helicopter operations makes overall statistics of limited value. Still, the general findings presented above are necessary to allow comparisons with results of specific helicopter operations.

Instructional flights recorded 784 accidents of which 54 (6.9%) confirmed a fatality. Aerial application, mostly crop-spraying activities, reported 614 accidents of which 42 (6.8%) were reported fatal. In contrast, personal flights reported 969 accidents with 162 (16.7%) confirmed fatalities and business flights 340 accidents with 53 (15.6%) fatal ones. Apart from the category 'unknown' these operation types are the most frequent in the database. They show a significantly higher number of fatal accidents among business and personal flights than in instructional and aerial application flights ($\chi^2 = 48{,}17$, $p < 0.001$, $df = 1$).

Future research may identify the specific circumstances of accidents in specialized operations. Some studies have already been published, for instance HEMS [6] and helicopter sling load operations [7], for subsets of the database, but other and more extensive studies are still wanting.

3. CONCLUSION

Helicopter accidents are specific for each operation. An overall analysis suggests that the most lethal occurrence in helicopter flights is weather-related and the least fatal are those that take place nearer to the ground, such as rollovers and accidents arising from the flare.

Significant causes and factors that lead to fatalities in helicopter operations do not seem to be helicopter-specific. They include light conditions, IMC conditions and in-flight encounter with weather, which have also shown to be dangerous in non-helicopter related accidents [8,9]. The relative absence of IFR-equipped helicopters or the possible presence of a low cloud base and limited visibility, as is often allowed in helicopter regulations, require further investigation to establish the particularities of the helicopter operations in these conditions.

The high fatality rates in personal and business flights rather than in specialized operations such as aerial application and instruction suggest that these general categories are in need of further research while the specificity of certain operations and the required expertise at least indicate that fatality rates are diminished.

The first results in this study indicate the possible lines of enquiry that serve the helicopter community best when it comes to lowering fatality rates. Analyzing subsets of helicopter accidents for which the NTSB database is particularly suited can further redress the limitations of the present study.

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