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Safety of twin-engine helicopters: Risks and operational specificity

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ABSTRACT

Objectives: To examine the difference between twin-engine and single-engine helicopter operations and accidents, and to understand the main factors that are associated with fatal twin-engine helicopter accidents.
Methods: Data concerning a ten-year period taken from the US National Transportation Safety Board online database on twin-engine helicopter accidents were analyzed and compared to a dataset of single- and twin-engine helicopter accidents in Part 135 Air Taxi and Commuter operations.
Results and recommendations: Twin-engine helicopters show a lower risk of accidents compared to single-engine helicopters but with a similar proportion of fatal accidents. Twin-engine helicopters show a frequent involvement in air medical operations, which expose pilots more often to night and IMC flight conditions that are significantly more often associated with fatal accidents. The differences in accident rate cannot be explained by the profile of the pilots, the kind of accident causes or their type of operations but may possibly be associated with differences in geographical location or type of organization.

1. Introduction to helicopter safety research

1.1. Previous research

Twin engines afford more power to an aircraft but their relative safety has been contested. In a recent study on twin piston-engine airplanes in general aviation, twin-engine aircraft are said to carry a higher risk of fatality compared with single-engine aircraft. However, their different flight profile — such as higher airspeed, service ceiling, aircraft yaw during engine failure — would make the comparison with single-engine aircraft accidents less relevant (Boyd, 2015). In the case of helicopters, the International Civil Aviation Organization (ICAO) published Amendment 1 to Annex 6, Part III, which recommends only multi-engine helicopters for instrument flight rules (IFR), night flights, flights to and from elevated helipads, and flights with visibility less than 1,500 m and a cloud ceiling of less than 600 feet. The recommendation suggests that twin-engine helicopters have a significant advantage in terms of safety. This perceived safety of twin-engine helicopters was questioned in a critical study of the available safety statistics (Fox, 1991) since, for instance, twin-engine helicopters cause higher fatalities or injuries per accident than their single-engine counterparts. In addition, it was suggested that twin-engine helicopters are by definition more complex machines in which more parts may be at risk of failing and causing accidents.

In the United States, twin-engine helicopters may be compared to single-engine helicopters as there are few restrictions implemented that follow the above ICAO amendment. Yet a risk analysis using the available denominator data provided by the US Federal Aviation Administration (FAA) only partly addresses the possible added safety of a second engine due to possible differences in helicopter operations. Helicopter accident analyses of US accidents have concentrated on specific operations, such as sling loads and aerial application (de Voogt et al., 2009; Manwaring et al., 1998), instruction (de Voogt & van Doorn, 2007), offshore versus onshore (Bye et al., 2018), and air medical operations (e.g., Baker et al., 2006). But the difference between single- and twin-engine helicopters is commonly disregarded as there are either too few twin-engine aircraft involved, such as the two examples in the dataset of de Voogt et al. (2009) or too few single-engine helicopters, as in Bye et al. (2018), to make such a comparison meaningful.

Risk factors for helicopter operations in general have highlighted the dangers of instrument meteorological conditions (Crognale & Krebs, 2011) and night flights (de Voogt, 2011), which are likely to be similar for both twin and single-engine aircraft. The examination of fatal injuries among helicopter pilots has emphasized the importance of shoulder harnesses and the dangers of aircraft fire (Krebs et al. 1995) as well as the need of better crashworthiness of helicopter designs (Taneja

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& Wiegmann, 2003). A study of UK and New Zealand helicopter accidents showed that light helicopters, as opposed to twin-engine turbine helicopters, accounted for 90% of fatal accidents in both countries. The majority of accidents occurred in private and training flights. In their error classification, attention and procedural errors were associated with the largest proportion of errors in both countries (Majumdar et al., 2009). The results of this latter study confirm the better safety of twin-engine helicopters but the relative absence of twin-engine helicopters in private and training flights does not allow this conclusion to be generalized to all operations.

In the following study, we assess the risks of twin and single-engine helicopters in the United States using the National Transportation Safety Board (NTSB) accident online database and the denominator data provided by the Federal Aviation Administration (FAA). This is followed by a study of about a hundred twin-engine helicopter accidents over a time-span of eleven years to determine the most common causes and factors. Finally, we compared accidents within the same time period of both twin and single-engine helicopters but only for Part 135 flight operations to determine the main differences in the accident profile of either group. The combination of these three studies aims to add insight in the different characteristics of accidents involving either twin or single-engine helicopters and makes recommendations that may mitigate the causes affecting twin-engine helicopters in general.

1.2. Part 135 flight operations

Flights operated under Title 14 Code of Federal Regulations Part 135 (FAA, 2020) pertain to commuter and air taxi operations. In other words, in most cases where a helicopter takes on a (paying) customer, the flight will fall under Part 135 flight rules. These rules have more restrictions than those following Part 91 General Aviation. Helicopter Part 135 operators require, for instance, more stringent maintenance practices, a mandatory drug and alcohol program, screenings of pilot records as well as adding pilot training requirements. The costs for liability insurance increases as well, which makes Part 135 operations generally more expensive than Part 91.

In addition to organizational requirements, pilots flying under Part 135 need to adhere to stricter visual flight rules (VFR), with a minimum cloud ceiling and 3 statute mile visibility in contrast with Part 91 where helicopters need to remain "clear of clouds" when below 1,200 feet, provided that the pilot can see and avoid obstacles and other aircraft.

Various specific operations have additional rules. Flight schools, for instance, operate using Part 61 or 141 although a solo student flight would fall under Part 91. Specialized helicopter tasks such as sling loads and aerial application also have additional flight rules. In a few instances, the operations of Part 91 and 135 seem to overlap. For instance, pilots may take friends and family on a sightseeing trip under Part 91 as long as the pilot is not paid for the work. In at least one case, the FAA has made an exception to allow activities with paying passengers to take place under Part 91. Air tour operators that take off and land at the same airport and stay within 25 miles of that airport do not have to adhere to Part 135 flight rules. Accident analyses have shown, however, that this 25-mile exception is not in the interest of safety (Ballard 2014).

Finally, prior to 2014 the FAA did not consider the medical flight crew as passengers during helicopter emergency medical services (HEMS) operations (NTSB, 2006). Without a patient on board, these flights were allowed to operate under Part 91 although some operators opted to conduct all their flights under Part 135. Apart from lower insurance costs, this also allowed pilots to fly in less restrictive weather conditions on the way to an emergency or during a positioning flight, which could apply to more than 50% of HEMS flights. Since safety concerns for HEMS are well documented (e.g., Baker et al., 2006; Aherne et al., 2018), this type of operation requires separate attention in our final analysis.

2. Risk and denominator data

The National Transportation Safety Board (NTSB, 2019) online database reported 97 accidents for twin-engine turbo-shaft helicopters in the United States from 1/1/2005 until 1/1/2015. In that same period, single-engine turbo-shaft helicopter accidents amounted to 646. There were 23 fatal accidents (23.7%) for twin-engine helicopters in this dataset versus 124 in the single-engine corpus (19.19%). The proportion of fatal accidents may serve as an indication of risk (de Voogt, 2010) but the difference between the proportions for single- and twin-engine helicopter fatal accidents is not significant ($\chi^2 = 1.0839$, df = 1, p-value = 0.297824). Still, there are an average of 2.06 fatalities per fatal accident for single-engine and 2.61 deaths per fatal accident for multi-engine helicopters.

The Federal Aviation Administration (FAA, 2019) aviation and statistics surveys provides denominator data for both single- and twin-engine turbo-shaft helicopters for the United States. It shows that for 2015, there were 3.10 times as many active single-engine turbine helicopters as there were multi-engine helicopters. Similarly, there were 3.27 times more hours flown by single-engine helicopters and 2.68 times as many landings in that same year. These values vary per year with 3.87 times more active single-engine helicopters in 2004 and 3.20 times more hours flown, for instance, but these latter values remain between 3 and 4 for the period between 2004 and 2015. Since there are 6.5 times more accidents reported for single-engine helicopters in the period between 1/1/2005 until 1/1/2015, the risk of an accident appears almost twice as likely for single-engine helicopters.

In previous research, it was pointed out that the differences in operations between single- and twin-engine helicopters may at least partially explain this difference. In other words, single-engine helicopters may not necessarily be riskier to operate. For instance, in 2015, there were 9.46 times as many landings by single-engine helicopters in Alaska than by twin-engine helicopters. Since the environment of Alaska may be considered more challenging (see e.g., Case et al., 2018; Thomas et al., 2000), it is not surprising it generally reports more accidents. Operations differ widely for single- and twin-engine helicopters. In 2015, the number of single-engine helicopters active in aerial observations ($N = 2{,}122$) and aerial applications ($N = 258$) was 19.47 and 12.9 times higher than for twin-engines ($N = 109$, $N = 20$). Also, the number of twin-engine helicopters in air medical operations ($N = 65$) was 4.06 times higher than for single-engines ($N = 16$). In terms of aviation use, twin-engine helicopters commonly used helicopters for business with a paid crew ($N = 418$ vs. $N = 111$) while single-engine helicopters are more common for business without paid crew ($N = 117$ vs. $N = 7$) in 2015. Similar contrasts are obtained if instead of number of active helicopters, the total hours flown by actual use are calculated. These differences complicate the comparison as some accident rates, for instance for air medical operations (see Baker et al., 2006), are commonly higher than those for other business operations.

A more general contrast of risk is found when comparing the number of hours flown during day and night. For 2015, the FAA reports 1,630,826 h flown by day and 281,265 by night for single-engine turbine helicopters and 425,387 and 158,769 h, respectively, for twin-engines. Twin-engine helicopters, therefore, fly a significantly higher number of hours at night than single-engine turbine helicopters ($\chi^2 = 47.3339$, df = 1, p-value < 0.01). In the same year, twin-engine helicopters flew 13,252 h in instrument meteorological conditions (IMC) during the day versus 756 h for single-engine helicopters, and 5,705 h IMC at night versus 1,042 h for single-engines. Previous research has shown that, in general, night flights have fewer accidents than day flights but more often lead to fatalities during IMC conditions (de Voogt, 2011). In air medical operations, night flights in IMC conditions were also a specific concern (Aherne et al., 2018).

In light of these complicating aspects when comparing risk between single- and twin-engine helicopters (see Table 1), a combination of two studies is provided. The first study consists of a general set of 97

Table 1
Denominator data for helicopter operations.

Turbine helicopters	single-engine	twin-engine *
Hours flown by day (2015)	1,630,826	425,387
Hours flown by night (2015)	281,265	158,769
Hours flown in IMC day (2015)	756	13,252
Hours flown in IMC night (2015)	1,042	5,705
Active helicopters in US (2015)	5458	1762
Hours flown (2015)	1,912	584
Landings, general aviation and air taxi (2015)	4,111,948	1,535,858
Landings in Alaska, general aviation and air taxi (2015)	116,751	12,347
Aerial observations (2015)	2,122	109
Aerial application (2015)	258	20
Air medical operations (2015)	16	65
Business with paid crew (2015)	11	418
Business without paid crew (2015)	117	7
Total number of accidents (1/2005–1/2015)	646	97
Number of fatal accidents (1/2005–1/2015)	124	23
Fatalities per fatal accident (1/2005–1/2015)	2.06	2.61

* FAA data only include data on “multi-engine” helicopters. No accidents for triple-engine helicopters have been attested in the NTSB database and their number is considered negligible for the purposes of this table.

accidents involving twin-engine helicopters that should help to determine if there are accidents that are especially common for twin-engine helicopters. This is then followed by a comparative study of single- and twin-engine helicopters of a similar size, with 99 single-engine and 24 twin-engine accidents, limited to Part 135 air taxi and commuter operations to limit the variety in types of operations. The two studies combined should provide a clearer insight in the specific issues confronting twin-engine helicopter operations and how the number of accidents for this type of helicopter may be mitigated in future.

3. Twin-engine helicopter accident analysis

3.1. Method

For an analysis of twin-engine helicopter accidents, we drew our dataset from the NTSB online database (NTSB, 2019). We collected all twin-engine turbo-shaft helicopter accidents in the United States from 1/1/2005 until 1/1/2015. This created a dataset of 97 accidents (see Table 2).

We used Pearson Chi-square analysis at the significance level of 0.05 to determine the significance of relations within the dataset.

Table 2
Comparative statistics for twin and single-engine helicopter accidents 1/1/2005–1/1/2015.

Helicopters	twin-engine		single-engine Part 135		twin-engine Part 135	
	N (fatal)	%	*N* (fatal)	%	*N* (fatal)	%
Number of accidents	97 (23)		99 (28)		24 (5)	
Number of fatalities	60		91		20	
Air medical	40 (13)	41.2	10 (4)	10.1	15 (4)	62.5
Pilot age (average)	51.8		47.2		55.3	
Accidents in Alaska	1 (1)	1.03	17 (3)	17.1	1 (1)	4.16
Accidents in Hawaii	1 (0)	1.03	18 (4)	18.1	0	0
Total pilot flight hours	8866		7953		10,081	
PIC primary cause	46 (14)	44.7	57 (18)	57.6	14 (4)	58.4
Equipment primary cause	36 (7)	35.0	30 (7)	30.3	7 (1)	29.3
IMC	10 (7)	10.3	4 (3)	4.0	3 (1)	12.5
Night	28 (11)	28.9	8 (5)	8.1	10 (3)	41.7

3.2. Results

3.2.1. People

Out of a total of 97 accidents, 23 (23.7%) were fatal with a total of 60 people suffering fatal injuries. An additional 27 people reported serious injuries. Only one accident suffered minor damage, others had substantial damage ($N = 76$) or were destroyed.

The average pilot age was 51.8 years with an average total flight time of 8,866 h. The lowest number of flight hours was 1,013 and the highest 36,000 with two unreported cases.

The primary cause of 36 accidents was related to equipment (35%), such as parts failure due to fatigue, wear, corrosion or maintenance. Of the remainder, 46 accidents were attributed to the pilot-in-command (44.7%). Out of 23 fatal accidents, 14 (60.9%) were attributed to the pilot-in-command, 7 (30.4%) to equipment, 1 unknown and 1 “other”. The 74 non-fatal accidents counted causes attributed to the pilot-in-command 31 (41.9%) times, equipment 25 (33.8%), unknown 5, crew 8, airport 1, environment 3 and object 1. There was no significantly higher proportion of pilot-in-command or equipment causes in the set of fatal accidents versus non-fatal accidents ($p > .05$)

3.2.2. Operations

Most of the operations in this accident set were conducted under Part 91: General Aviation ($N = 59$) with 14 fatal accidents. Part 135: Air Taxi and Commuter Non-scheduled operations had 24 accidents of which 5 were fatal. Part 133: Rotorcraft Ext. Load saw 6 cases of which one was fatal and 8 accidents were classified as Public Use with 3 fatalities. Neither Part 135 nor Part 91 had a significantly higher proportion of fatal accidents ($p > .05$).

There were 40 (41.2%) accidents that were conducted with air medical purposes. They were found under Part 135 with 14 cases, Part 91 with 25 cases and Public Use in 1 case. Out of the total of air medical operation accidents, 13 (32.5%) were fatal and 27 non-fatal. The number of fatal accidents was not significantly higher than for the rest of the dataset ($p > .05$).

The highest number of accidents was found in California (N = 13) and Texas (N = 10) with 4 and 1 fatal accident, respectively.

3.2.3. Environment

Weather conditions were reported as IMC in 10 (10.3%) cases and the remainder VMC with one case not reported. Most accidents occurred in daylight conditions with 28 (28.9%) occurring at night, 2 at dawn and 1 at dusk.

Seven out 23 fatal accidents were operated in IMC, which is a significantly higher proportion than the number of non-fatal accidents in IMC ($N = 3$), ($\chi^2 = 14.0086$, df $= 1$, $p < .01$). Eleven out of 23 fatal accidents were operated at night, which is a significantly higher proportion than the number of non-fatal accidents at night ($N = 16$), ($\chi^2 = 5.9982$, df $= 1$, $p = .014321$). Seven out of eight flights that occurred at night in IMC conditions were fatal. Only 2 accidents were reported that occurred during the day in IMC conditions and both were not fatal.

4. A comparison of twin and single-engine helicopter accidents in Part 135 operations

4.1. Method

The methods were comparable to the previous analysis and were again limited to the period between 1/1/2005 and 12/31/2015. In this dataset, we include both single- and twin-engine turbo-shaft helicopters but we only selected accidents from Part 135 operations, which are nonscheduled air taxi and commuter flights (see Table 2). They exclude sling load, aerial application, instruction, and other specialized operations for which single- and twin-engine helicopters are not necessarily equally well-equipped.

We used the NTSB online database to select Part 135 operations limited to the United States and excluded accidents without a final accident report in the database.

4.2. Results

4.2.1. Single-engine

4.2.1.1. People. The single-engine helicopters accidents of this period had a total of 99 accidents of which 28 were fatal (28%) with a total of 91 fatally injured people, or an average of 3.25 fatalities per fatal accident. An additional 36 people were left with serious injuries. Helicopters were destroyed ($N = 17$) or else had substantial damage.

The average pilot age in this group of accidents is calculated at 47.2 years with 2 unreported cases. The average total flight hours is 7,953 h also with 2 unreported cases.

The primary cause of the accident was attributed to equipment in 30 cases (30.3%) and in 57 cases to the pilot-in-command (57.6%). Out of 28 fatal accidents 7 (25%) causes were attributed to equipment, 2 were unknown, 1 to ATC, and 18 (64.3%) were attributed to the pilot-in-command. Out of 71 non-fatal accidents 37 (52.1%) had its primary cause attributed to the pilot-in-command, 23 (32.4%) were attributed to equipment, 5 were unknown, 3 to the environment, 1 to the company/operator, 1 to the pilot of another aircraft. There was no significantly higher proportion of pilot-in-command or equipment causes in the set of fatal accidents versus non-fatal accidents ($p > .05$)

4.2.1.2. Operations. Out of 28 fatal accidents, 4 (14.3%) were operated for air medical purposes, while the remaining 71 non-fatal accidents only had 6 air medical flights, but this difference was not significant (p greater than 0.5).

The highest number of accidents was found in Hawaii ($N = 18$), Alaska ($N = 17$), and the Gulf of Mexico ($N = 11$) with 4, 3 and 3 fatal accidents, respectively. For two accidents, the state location was not reported.

4.2.1.3. Environment. IMC conditions were reported in 4 (4%) cases of which 3 were fatal. Only 8 accidents took place during night conditions (8.1%) with 2 at dusk. One accident did not report light conditions and the remainder took place during daylight. Yet 5 out of those 8 night accidents were fatal. Two accidents occurring at night and in IMC conditions were fatal, one IMC flight took place during the day and was fatal, and one IMC flight during the day was not fatal. There is a significantly higher proportion of fatal accidents at night than during the day ($\chi^2 = 5.0237$, df = 1, $p = .025002$).

4.2.2. Twin-engine

4.2.2.1. People. The twin-engine helicopter accidents under Part 135 totaled 24 for this period, as reported in study 1. There were 5 fatal accidents (20.1%) with a total of 20 fatalities, or an average of 4 fatalities per fatal accident. An additional 12 serious injuries were reported. All aircraft were either destroyed (N = 4) or substantially damaged ($N = 20$).

The average pilot age was 55.3 with an average of 10,081 total flight hours.

The primary cause of accidents was attributed to equipment or maintenance in 7 cases (29.2%) of which 1 was fatal, and to the pilot-in-command in 14 cases (58.4%) of which 4 were fatal, one was attributed to the co-pilot, one to an object, and one cause was unknown; none of these latter causes were part of a fatal accident.

4.2.2.2. Operations. Out of 24 flight accidents, 15 (62.5%) were conducting an air medical flight of which 4 were fatal but the difference in fatality between medical and non-medical flights was not significant ($p > .05$).

The highest number of accidents was found in Texas (N = 4) and Illinois (N = 3) with 0 and 2 fatal accidents, respectively. There was one accident reported for Alaska, none for Hawaii and the Gulf of Mexico. For two accidents the location was not reported.

4.2.2.3. Environment. IMC conditions were found in 3 cases (12.5%) of which 1 was fatal and took place at night. Ten accidents occurred at night (41.7%) of which 3 were fatal.

4.2.3. Comparison of single- and twin-engine flight accidents

4.2.3.1. Part 135. Twin-engine helicopters operating under Part 135, had a significantly higher proportion of air medical flights in the accident dataset than single-engine helicopters ($\chi^2 = 32.7515$, df = 1, $p < .00001$). In addition, twin-engine helicopters had a significantly higher proportion of night flights than single-engine helicopters ($\chi^2 = 17.4423$, df = 1, $p = .00003$).

There was no significant difference between single- and twin-engine helicopter accidents in terms of pilot age and experience, or in the primary cause of the accident. For both types of helicopters night flights and IMC conditions are especially dangerous.

Twin-engine accidents show a higher number of fatalities per accident (4) than single-engine cases (3.25), with twin-engine helicopters showing 20.1% of accidents being fatal versus 28% for single-engines.

4.3. General twin-engine helicopter operations

The overall study of twin-engine helicopter accidents shows slightly different numbers compared to Part 135 operations. There are 2.61 fatalities per fatal accident, which is lower than 4.0 for Part 135 twin-engine helicopter accidents and also lower than 3.25 for single-engine Part 135 accidents. In contrast, the proportion of fatal accidents is slightly higher (23.7%) in general than for Part 135 twin-engine helicopters (20.1%) but lower than for Part 135 single-engine helicopters (28%).

In general, 40% of twin-engine accidents occur during air medical operations and this number increases to 62.5% for Part 135 operations versus 14.3% for single-engine Part 135 accidents. Similarly, IMC conditions were reported for 10.3% of accidents with twin-engine helicopters and this increased to 12.5% for Part 135 operations but was contrasted with only 4% for single-engine Part 135 accidents.

Finally, the geographic distribution of single- and twin-engine helicopter accidents seems markedly different. For instance, Alaska and Hawaii reported a high number of single-engine helicopter accidents but particularly few twin-engine examples.

5. Discussion

ICAO recommends only multi-engine helicopters for IFR, night flights, helipad operations, and in low visibility situations. In line with this recommendation, the FAA reports a significantly higher number of hours at night and/or in IMC conditions for twin-engine helicopters. Flights in these conditions also take up the main part of the fatal accidents of twin-engine helicopter operations. One may argue that higher exposure to these conditions puts twin-engine helicopter operations at a higher risk.

The ICAO recommendation also explains the higher proportion of air medical flights using twin-engine helicopters as they often include helipad operations. The number of fatal accidents for air medical operations was higher than for all operations combined but not significantly so. However, in the case of Part 135 operations, 9 out of 10 accidents with twin-engine helicopters and air medical purposes were operated at night and included all three night-time fatalities, suggesting that air medical flights are more likely to feature twin-engine helicopters in night-time operations.

On average pilots were older and more experienced when operating twin-engine helicopters but this was not significantly connected with specific types of accidents or injuries. In previous research, it was found that differences in types of accidents between pilots with more or with less than 10,000 h can be found in sling-load operations but not with aerial applications (de Voogt et al., 2009), suggesting that a more fine-grained analysis in terms of type of operation may also affect the difference between single- and twin-engine accidents.

The importance of operation-specific analysis was shown in the significantly higher proportion of air medical flights using twin-engine aircraft. As with the higher proportion of night flights, the greater involvement of twin-engine helicopters in air medical flights only suggests a higher risk, predicting a higher proportion of (fatal) accidents compared to single-engine helicopters (Baker et al., 2006). Again, this does not seem to be the case and would recommend the continued use of twin-engine helicopters in EMS.

The remaining risk factors between single- and twin-engine helicopter operations appear mostly insignificant. They share the common danger of IMC conditions and night flights (Aherne et al., 2018; Crognale & Krebs, 2011; de Voogt, 2011). But as mentioned above, twin-engine helicopters conducted a significantly higher proportion of night flights, which did not result in higher accident or fatality rates compared to single-engine helicopters.

This study agrees with Fox (1991) that the type of helicopter operations significantly affects accident statistics and precludes a proper comparison between twin and single-engine helicopters in terms of overall safety. This seems particularly true outside the United States (Majumdar et al., 2009). But, when corrected for certain operations, twin-engine helicopters appear to take on more risk with more frequent night flights and IMC conditions while their proportion of fatal accidents compared to that of single-engine helicopters is not significantly different. Similarly, they are more often involved in air medical operations, a type of operation that is reported as having a higher accident rate. Instead, there are 6.5 times more accidents reported for single-engine helicopters in the studied 11-year period while there are only 3.27 times more hours flown, making the risk of accidents for single-engine helicopters nearly twice as high than for their twin-engine counterparts even though the latter also fly more hours in high-risk night-time and IMC conditions.

The main difference between the two types of helicopters is found in the geographical distribution of both landings and accidents. Following Case et al. (2018), Grabowski et al. (2002), and Thomas et al. (2000), regions such as Alaska may prove to be more challenging. In future research, a comprehensive geographical analysis of accidents rates per state may show whether these differences in location could partly explain the higher overall accident rate of single-engine helicopters.

The ICAO recommendation to only use multi-engine helicopters for IFR, night flights, low visibility and helipad operations is supported by the accident analysis of single- and twin-engine helicopters. Unfortunately, the reasons for their safer operation is not immediately apparent. Pilot experience does not seem to be associated with higher accident rates and the type of causes are also not significantly different. One may argue that the main difference may be found at the level of incidents and occurrences in which case a line observation safety audit may reveal the necessary detail (Helmreich, 2000). The monitoring of normal operations is a practice that is already supported by ICAO for airliners (e.g., Maurino, 1998) and may find an additional purpose in helicopter operations.

Although this study largely confirms that twin-engine helicopters present a lower risk than single-engine helicopters, it does not explain why this would be the case. On the contrary, the type of operations that characterize an important part of the twin-engine helicopter category would suggest the opposite. The type of causes as well as the pilot characteristics do not provide clear indications that either the machine or the pilot have a particularly different profile. Future research may delve deeper into the accident narratives but may also address other aspects of twin-engine helicopter operations. The expense of twin-engine machines may make an advanced organizational infrastructure with better training and maintenance facilities more likely, which may in turn reduce the overall number of accidents.

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