A comparative statistical analysis of global trends in civil helicopter accidents in the U.S., the EU, and the CIS

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Abstract. With helicopter operations increasing worldwide for varying usage and purposes, it is important to identify changes in helicopter accident trends. This paper studies the trends in civilian helicopter accidents in the United States, the European Union, and the Commonwealth of Independent States, and evaluates helicopter flight safety. Comparative analysis was performed, focusing on statistics and accident reports from Federal Aviation Administration, International Helicopter Safety Foundation, United States Helicopter Safety Team, National Transportation Safety Board, European Union Aviation Safety Agency, and Interstate Aviation Committee. The overall helicopter accident trends by flight time, engine type, and phase of flight were considered. The differences among the groups were identified, and the flight safety of helicopter was compared with that of other types of aircraft. In conclusion, gas-turbine engine helicopters showed a significant increase in the number of accidents. Regarding phase of flight, takeoff, landing, maneuvering, and en-route reported the most number of accidents. This study emphasizes the need for more profound research on improving helicopter flight safety by analyzing the global trend of helicopter accidents.

1. Introduction

According to FlightGlobal’s October 2018 report, there are a total of 38,536 helicopters in existence worldwide [1]. By December 2018, it was recorded that 32,372 helicopters are currently in operation [2], which is a 14.7% increase from 2012 (28,230). North America leads by accounting for 34.3% of the in-service helicopters, with 81.9% registered in the U.S. Europe accounts for 28% of the total in-service helicopters, with Russia operating the highest number in the region with 26.7% [1]. Airbus’s helicopter civil market forecast in 2017 [3] and Geach O’s helicopter market update in 2019 [4] both show the global demand for helicopters will continue to grow.

In 2000, Franklin D H et al. analyzed the trends and causes of helicopter accidents in the U.S. from 1963 to 1997 [5]. In conclusion of this work, the research emphasized the importance of the rotary-wing aircraft and called for extended efforts to reduce its accidents [5]. Airworthiness certification system, technical system, pilot education system, and etc. are used in efforts to reduce the helicopter accident rate. In the past, these efforts were carried out domestically, but as the civil helicopter usage is becoming more universal, international efforts with various international organizations, such as International Helicopter Safety Foundation (IHSF) is putting forth more effort.

As mentioned, the global demand for helicopters is growing, and the trend of helicopter accidents are changing alongside. Analyzing the said trend is essential in researching ways to increase the...
helicopter flight safety. Therefore, the paper aims to analyze the trend of accidents of civil helicopters registered and operated by the U.S., the EU, and the CIS.

2. Data

The accident trend analysis was performed based on statistical data and helicopter accident reports from the United States, the EU, and the CIS. In the U.S., the Federal Aviation Administration (FAA)’s data and United States Helicopter Safety Team (USHST)’s data from National Transportation Safety Board (NTSB) were considered; in the EU, the European Union Aviation Safety Agency (EASA)’s data was considered. Lastly, in the CIS, the Interstate Aviation Committee (IAC)’s data and annual aircraft accident reports were considered. Then, using the comparative statistical analysis of accident trends, the total number of helicopter accidents and three different trend groups, including flight time, engine type, and phase of flight, were analyzed.

3. Results and discussion

3.1. Analysis of the total number of civil helicopter accidents

![Figure 1. The total number of rotorcraft accidents from 1983 to 2018 in the U.S.](image)

Figure 1 shows the decreasing tendency of helicopter accidents from 1983 to 2018 in the U.S. with data from IHSF and USHST [6, 7]. Comparing the average value for the first and the last three years of this period, it was observed that the total number of helicopter accidents went from 244 to 117.67 — a 51.78% decrease. The number of fatal accidents also decreased from 36.66 to 20.33, which is a 45% decrease. When analyzing the ratio of fatal accidents to the total number of accidents, however, the number had increased from 15% to 17.3%. This shows that present-day helicopter accidents are more likely to be fatal than those in the past. The USHST Safety Report [8] further supports this: from January to October 2019, there were 111 helicopter accidents with 21 of them fatal, marking 18.92% of the total accidents as fatal.

Figure 2a shows the number of helicopter accidents in the EU based on the data collected from EASA [9]. In the EU, the average value of the total number of accidents from the first three years in the figure was compared with that of the last three years, and it was observed that the total number of accidents decreased by 22.5%. The total number of non-fatal accidents was analyzed likewise and showed a 42.33% decrease (71.67 to 41.33). Also, the number of fatal accidents from 2009 to 2015 decreased by 38.07% (14 to 8.67). However, the number began inclining after 2015 all the way to 2018, reaching the same number of fatal accidents as it did in 2008. The average ratios of all accidents to fatal accidents
were 15.5% for the first three years and 13.5% for the last three year, which showed an insignificant difference.

![Graphs](image)

**Figure 2.** The number of helicopter accidents in the EU (a) and the CIS (b).

Figure 2b shows the number of helicopter accidents in the CIS based on the data from IAC [10-20]. In the CIS, the average number of accidents from the first three years was 15.67 while the average from the last three years was 24.67 — this is a sharp increase of 57.43%. The number of fatal accidents analyzed likewise also shows an increase of 24.1% (9.67 to 12).

| Year | Section 1 | Section 2 | Section 3 | Section 4 | Commercial operation | CIS |
|------|-----------|-----------|-----------|-----------|----------------------|-----|
|      | EU        | EU        | CIS       | CIS       |                      |     |
| 2008 | 4(0)      | 12(2)     | 16(3)     | 53(4)     | 12(8)†               |     |
| 2009 | 3(1)      | 5(2)      | 32(6)     | 54(10)    | 13(7)                | 4(2)|
| 2010 | 1(0)      | 9(2)      | 25(6)     | 57(6)     | 9(5)                 | 5(3)|
| 2011 | 5(1)      | 5(2)      | 27(8)     | 53(6)     | 10(4)                | 7(4)|
| 2012 | 5(0)      | 9(1)      | 23(6)     | 39(4)     | 11(5)                | 9(4)|
| 2013 | 2(1)      | 4(0)      | 19(4)     | 53(7)     | 9(2)                 | 7(4)|
| 2014 | 1(0)      | 7(1)      | 14(0)     | 47(8)     | 11(5)                | 12(6)|
| 2015 | 0(0)      | 13(2)     | 9(2)      | 38(2)     | 11(5)                | 11(5)|
| 2016 | 3(1)      | 9(3)      | 17(1)     | 40(4)     | 12(3)                | 18(9)|
| 2017 | 2(0)      | 12(1)     | 17(2)     | 36(4)     | 11(4)                | 9(7)|
| 2018 | 4(0)      | 19(2)     | 18(2)     | 33(6)     | 17(10)               | 7(3)|
| Total| 30(4)     | 104(18)   | 217(40)   | 503(61)   | 126(58)              | 92(50)|

| Description   |
|---------------|
| a Offshore Commercial Air Transport Helicopters. |
| b Commercial Operations – Other than Offshore. |
| c Specialized Operations. |
| d Non-Commercial Operations. |
| e Number of total accidents including serious incidents, fatal/non-fatal accidents (Fatal accidents) for EU. |
| f Number of total accidents (Fatal accidents) for CIS. |

Table 1 includes the data of helicopter operations in the EU in four main sections: (1) passenger and cargo flights to and from offshore oil and gas installations, conducted by EASA Air Operators Certificate
(EASA AOC) holders with certified helicopters, (2) all passenger and cargo flights not used in offshore oil and gas operations, conducted by EASA AOC holders with certified helicopters, (3) specialized operations involving certified helicopters, such as air ambulance, advertisement, photography, with EASA MS as state of operator or state of registry, and lastly, (4) non-commercial operations involving certified helicopters, with EASA MS as state of operator or state of registry [9]. For the CIS, all commercial flights and general aviation (GA) were included [10-20].

Section 1 showed an irregular trend of decrease and increase. In section 2, the average number of fatal accidents was 1.64 with the number remaining without any significant increase or decrease. The number of serious incidents, however, showed a gradual decrease up until 2013, and then a sharp increase afterwards.

In section 3, the total number of accidents exhibited a sharp decline, going from 32 accidents in 2009 to 9 in 2015. This is a 71.88% decrease. Fatal accidents showed a similar decline from 2011 to 2014. In 2016, the total number of accidents began rising, almost doubling from 2015. Fatal accidents also increased beginning in 2014, and both numbers plateaued since.

The accidents in non-commercial operations demonstrated in Section 4 accounted for 58.9% of all recorded number of accidents from 2008 to 2018. The average value of total accidents in the first three years of the graph was compared with that of the last three years of the graph. For total number of accidents, the analysis showed 33.55% decrease (54.67 to 36.33) comparable to the 30% decrease for the number of fatal accidents (6.67 to 4.67). The ratios of the number of fatal accidents to that of all accidents in each section of the EU are 13.33%, 17.3%, 18.43%, and 12.13%, respectively.

In the CIS countries, 57.53% of accidents in the last 11 years occurred in commercial operations and 42.47% in GA. Fatal accidents accounted for 46% of all recorded commercial operations and 54.84% of all recorded GA. The average number of total accidents in the first three years was compared to that of the last three years: in commercial operations, there was an increase from 11.33 to 13.33; in GA, there was a more significant increase from 4.33 to 11.33. Although fatal accidents in commercial flight showed a slight decrease of 6.67 to 5.67, fatal accidents in GA showed significant increase from 3 to 6.33.

3.2. Analysis of a number of civil helicopter accidents per 100,000 flight hours

Data was collected from multiple sources for figure 3. For all types of helicopter accidents in the U.S. and the CIS, the data for 1999 to 2008 was collected from IAC’s 2010 report [19]; Roskop L’s report in 2018 [21] was considered for the data from 2009 to 2016 in the U.S., and USHST’s 2019 report [7] was considered for the data in 2017 to 2018. For the CIS data, the upper appendage ‘b’ from 2000 to 2018 considers only the accidents in commercial flights, and not GA [10-12, 17].

For the U.S., the total number of accident average from the first three years compared to that of the last three showed 56.3% decrease (8.2 to 3.58), and the same analysis for fatal accidents showed a 54.5% decrease (1.34 to 0.61). On the other hand, USHST November 2019 report including the data from January to October 2019 revealed the fatal accident rate has increased to 0.69 and the overall accident rate to 3.67 [8]. It is important to note, however, the total active helicopter flight time in the U.S. was approximately 2.1 million hours [5] and the flight time accumulated in 2019 from January to October exceeds 3 million hours [8]. Thus, despite the increase in accident rates this year, it can be assumed that significant progress has been made in improving helicopter flight safety.

The CIS showed a similar trend as the overall accident rate decreased up until 2012, but the rate began to increase again in 2013. Moreover, the rate of fatal accidents in commercial flight showed a sharp increase in 2018. According to IAC’s report, the accident rates of all aircraft types other than a helicopter are as follows: the average of non-fatal accidents by flight time from 2000 to 2008 was 1.26 while the average of fatal accidents was 0.52 [19, 22]. Since figure 3 also demonstrates the total number of accidents over each year’s entire flight time, the data allows a comparison of accident rates between helicopters and other aircraft types, it is sufficiently demonstrated that helicopter accidents happen more frequently than all the other aircraft accidents. Additionally, the paper considered the accident rate by aircraft weight. From 2009 to 2018, the average accident rate for commercial flight aircraft with a takeoff
weight of 10 tons or more was 0.145 and the average rate for fatal accidents was 0.06 [10, 15]. For a takeoff weight of less than 10 t, the average accident rate from 2009 to 2018 was 7.64, while the rate for fatal accident was 3.63 [10, 15]. This shows that although the average accident rate of helicopter is lower than that of heavy-weight aircraft, it is higher than the average for light-weight aircraft.

![Figure 3](image)

**Figure 3.** The number of accidents per 100,000 flight hours for total accidents (a) and fatal accidents (b) from 1999 to 2018 (a all types of operations, b without GA).

### 3.3. Analysis of helicopter accidents based on engine type

The commercial production of helicopters with gas-turbine engines in the U.S. began in 1958, and increased rapidly [5]. By 1982, it even surpassed the production of reciprocating engines [5]. A similar trend followed suit worldwide, and in 2018, the gas-turbine engine helicopters accounted for 69.1% of all in-operation helicopters, showing a 90% increase from 2004 [2, 23]. Considering this significant increase, an accident analysis by engine type was performed.

![Figure 4](image)

**Figure 4.** The number of fatal accidents per 100,000 flight hours by the Federal Aviation Regulations and engine installation from Jan 2009 through Aug 2018 [21]. (a Airworthiness Standards: Transport Category Rotorcraft; b Airworthiness Standards: Normal Category Rotorcraft).
Figure 4 shows the number for reciprocating engines stayed relatively higher than that of gas-turbine engines. This suggests that gas-turbine engines provide higher flight safety. However, after analyzing the US, 2000, 2001, and 2006 accidents of helicopters registered, the percentage of accidents for each engine type was 39–45% for the single reciprocating engine, 45–51% for single gas-turbine engine, 8–10% for the rest [24]. Furthermore, the NASA technical report [5] showed the number of accidents for reciprocating engines has decrease over the years; gas turbine engines also indicated a significant decrease in 1970s, but showed no remarkable decrease since then. Furthermore, figure 4 shows twin gas-turbine engines have lower number of fatal accidents than single turbine engines do, indicating that having an extra engine may increase the chance of survival in the event of an engine failure.

It is mentioned above that gas-turbine engines seem safer in the past, but the report on fatal accidents shows contrasting evidence. When the numbers of accidents per flight time for single and twin gas-turbine engines were combined, it was higher than that of reciprocating engines. The total number of accidents may be lower for the gas-turbine engine, but it is more prone to fatal accidents than the reciprocating engine does. In the past, reciprocating engines were widely used for various flight purposes, but the gas-turbine engines became a more popular choice in the recent years. As the usage for gas-turbine engines further dominate the industry, it is critical to reconsider the flight safety for said engine due to its higher likelihood for fatal accidents.

Table 2 shows the number of accidents according to the installed engine types categorized by operation classifications in the EU. It then compares the data from 2018 to the average data collected from 2008 to 2017 [9]. In 2018, 25 accidents from reciprocating engine helicopters are calculated across all three classifications, while 45 accidents from gas-turbine engines are recorded. For the rate of accidents in different operation classifications in 2018, commercial operations excluding offshore accounted for 27.14% of total helicopter accidents, specialized operations accounted for 25.71%, and non-commercial operations accounted for 47.14%.

Table 2. Distribution of accidents in the EU.

| Engine type          | Section 1\(^a\) | Section 2\(^b\) | Section 3\(^c\) |
|----------------------|-----------------|-----------------|-----------------|
|                      | Avg. \(^d\)   | 2018     | Avg. \(^d\) | 2018 | Avg. \(^d\) | 2018 |
| Reciprocating engine | 1.7            | 0       | 6       | 5    | 30.1      | 20   |
| Gas turbine engine   | 6.8            | 19      | 14      | 13   | 16.9      | 13   |

\(^a\) Commercial Operations – Other than Offshore.

\(^b\) Specialized Operations.

\(^c\) Non Commercial Operations.

\(^d\) Average number of helicopter accidents from 2008 to 2017.

Table 2 also shows that section 1 and 2 indicate a much higher accident rate for the gas-turbine engines, while section 3 exhibits contrasting evidence. In comparing the 10-year average for the number of helicopter accidents to the total number of accidents from 2018, it is noted that gas-turbine engines for commercial operations excluding offshore stands alone for exhibiting a significantly higher number of accidents in 2018 than that from a 10-year average. This supports the analysis based on figure 4: the demand for helicopters with gas-turbine engine is increasing, but so is the accident rate for said helicopter type.

Table 3 presents a number of helicopter accidents in CIS from 2008 to 2018, according to engine types, accident types, and then into operation types [10-20, 25]. As of May 2017, a total of 2,560 helicopters were registered in the CIS. Among that number, 93.8% had gas-turbine engines. The ratio is even higher for the active helicopters, with a staggering 98.6% them having gas-turbine engines [2].

When focusing on the total number of accidents, it is observed that those by gas-turbine engine helicopters accounted for 73.52% of all helicopter accidents in the CIS for the last 11 years. Gas-turbine engine helicopters also recorded 84 fatal accidents, which is more than three times that of reciprocal engine helicopters. Comparing the average number of non-fatal accidents in the first and the last three years from the data further confirmed the high risk of gas-turbine engine helicopters: the average value
increased from 4.33 to 5.33 for reciprocating engines, but for gas-turbine engines, it increased from 11.33 to 19.33. Similarly, the same comparison for fatal accidents showed a slight increase for reciprocating engines (from 2 to 2.33), while the number for gas-turbine engine showed a greater increased (from 7.67 to 9.67).

Table 3. The number of non-fatal and fatal accidents in the CIS by engine and operation type.

| Year | Reciprocating engine | | | Gas turbine engine | | |
|------|----------------------|------|----------------------|------|
|      | Non-fatal accident | Fatal accident | Non-fatal accident | Fatal accident |
|      | Com. a | GA | Com. a | GA | Com. a | GA | Com. a | GA |
| 2008 | 0 | 2 | 0 | 2 | 4 | 0 | 8 | 0 |
| 2009 | 1 | 0 | 0 | 2 | 5 | 0 | 7 | 2 |
| 2010 | 2 | 2 | 1 | 1 | 2 | 0 | 4 | 2 |
| 2011 | 0 | 3 | 0 | 2 | 6 | 0 | 4 | 2 |
| 2012 | 0 | 3 | 0 | 2 | 6 | 2 | 5 | 2 |
| 2013 | 1 | 1 | 0 | 3 | 6 | 2 | 2 | 1 |
| 2014 | 2 | 3 | 0 | 2 | 4 | 3 | 5 | 4 |
| 2015 | 2 | 2 | 0 | 3 | 4 | 4 | 5 | 2 |
| 2016 | 2 | 3 | 0 | 4 | 7 | 6 | 3 | 5 |
| 2017 | 1 | 2 | 2 | 0 | 6 | 0 | 2 | 7 |
| 2018 | 0 | 1 | 0 | 1 | 7 | 3 | 10 | 2 |
| Total | 11 | 22 | 3 | 22 | 57 | 20 | 55 | 29 |

*Commercial flight.

3.4. Analysis of the number of accidents by phase of flight

Helicopter operation consists of more flight phases than fixed-wing aircraft operation does. Thus, an analysis of helicopter accidents based on phases of flight was carried out.

![Figure 5](image-url)

**Figure 5.** The number of helicopter accidents registered in the U.S. by phases of flight in 2000, 2001 and 2006 (a) [24], and from 2012 to 2016 (b) [26-30]. (LDG (landing), ENR (en-route), MNV (maneuvering), Hovering, TOF (takeoff), APR (approach), STD (standing), TXI (taxi), EMG (emergency descent), ICL (initial climb), UND (uncontrolled descent), UNK (unknown)).

US-JSHAT’s 2011 data reported a total of 523 helicopter accidents from 2000, 2001 and 2006, according to phase of flight the accident occurred [24]. In figure 5a en-route, maneuvering, hovering,
and takeoff showed higher number of accidents, with landing showing the highest number. Similarly, maneuvering and hovering showed higher number of fatal accidents, with en-route showing the highest number. For Figure 5b, 2012 to 2016 NTSB database for Part 135 and GA was considered [26-30]. Landing, en-route, and takeoff showed higher number of accidents, with maneuvering dominating as phase of flight with the highest number of accidents. For fatal accidents, maneuvering, en-route, approaching, and takeoff accounted for 86.8%.

Table 4 shows the number of helicopter accidents registered in the EU and Russia by phases of flight [9, 31]. Data are shown separately due to differences in categorization of phase of flight between the EU and Russia. For the EU, section 1 displays a decrease in accidents for all phases, except for approach, which shows a significant increase. Section 2 displays even more significant increases for takeoff and landing. There are no significant differences between the 10-year average and 2018 data for all phases of flight for section 3, but it is noteworthy that 2018 data for standing has increased almost 7 times compared to its 10-year average. In section 4, the number of accidents during landing and en-route has decreased, while during takeoff and maneuvering remained high. Overall, maneuvering, takeoff, landing, and en-route demonstrated to be more dangerous. The data from Russia are comparable to that of the EU: approach, takeoff, landing, and en-route demonstrated to be more dangerous, and together they accounted for 75.9% of all accidents from 2012 to 2016.

Table 4. Number of accidents with helicopter, registered in EU and Russia, by phase of flight.

| Phase of flight | EU | Russia |
|-----------------|----|--------|
|                 | Section 1<sup>a</sup> | Section 2<sup>b</sup> | Section 3<sup>c</sup> | Section 4<sup>d</sup> | Phase of flight | 2012-2016 |
|                 | Avg. 2018 | Avg. 2018 | Avg. 2018 | Avg. 2018 | En-route | 28 |
| Landing         | 0.8 | 0.8 | 2.5 | 12.1 | 5 | 28 |
| En-route        | 1.2 | 1.2 | 3.1 | 9.8 | 2 | Approach | 16 |
| Take-off        | 0.1 | 0   | 3.1 | 8.4 | 9 | Take-off | 11 |
| Manoeuvring     | 0.1 | 0   | 8.8 | 6   | 8 | Landing | 8 |
| Approach        | 0.1 | 0.9 | 3.1 | 6.1 | 3 | Descent | 8 |
| Taxi            | 0.2 | 0   | 0.1 | 2.8 | 1 | Climb | 5 |
| Unknown         | -   | 0.6 | 0   | 2.4 | 4 | Hovering | 4 |
| Standing        | 0.1 | 0.4 | 0.3 | 1.8 | 3 | Low-level flying | 3 |
| Total           | 4   | 19  | 18  | 33  | 83 |

<sup>a</sup>Offshore Commercial Air Transport Helicopters.
<sup>b</sup>Commercial Operations – Other than Offshore.
<sup>c</sup>Specialized Operations.
<sup>d</sup>Non Commercial Operations.
<sup>e</sup>Average number of helicopter accidents from 2008 to 2017.

4. Conclusions

The largest number of helicopter accidents occurred in the US, followed by the EU and the CIS. The total number of helicopter accidents has decreased in the U.S. and the EU, but the number of fatal accidents showed no significant decrease. The CIS, on the other hand, showed an increase in the total number of accidents. In recent years, the number of fatal accidents has increased also. The accident analysis according to flight operations based on 2008 to 2018 data indicate that 58.9% of accidents occurred in GA in the EU, while the CIS reported 57.5% of accidents to have occurred in commercial flights. Efforts have been made regarding the increasing trend in helicopter accidents, but further research is necessary to ensure higher flight safety and reduce the number of fatal accidents.

Also, the number of civil helicopter accidents per 100,000 flight hours was analyzed based on the data from the U.S. and the CIS. The analysis confirmed that helicopter flight safety is generally lower than that of fixed-wing aircraft. For commercial flights, helicopter flight safety was in between the safety of heavy and light aircraft.
Helicopter accident analysis by engine type revealed that the accidents with reciprocating engines were more frequent in the early stages of helicopter operation history, but as gas-turbine engines became more popular, the trend changed significantly in the 2000s. Recent data show the number of helicopter accidents with gas-turbine engines are similar and/or more to that of reciprocating engines. This indicates that gas-turbine engine helicopters are increasing in usage and in demand. As a result, further research is required to improve the flight safety of gas-turbine engine helicopters.

Analysis of helicopter accidents by phase of flight confirmed that most of the accidents occurred during takeoff, landing, maneuvering, and en-route. This suggests that although the helicopter’s relatively free maneuvering provides many advantages compared to fixed-wing aircraft, but it is also a potential main cause of accidents in flight.

The study shows that the flight safety of civilian helicopters around the world continues to be questionable. The reliability of helicopter would be challenged as well if the number of fatal accidents fails to show a significant reduction. Helicopters with gas-turbine engines are becoming more prevalent in various fields of operation, contributing more complexity and diversity to aviation accident trends. Lastly, flight phases with the highest risk remained almost unchanged. The danger of these high-risk phases leads to either increase the constraints on helicopter activities or accept the risk in flights.

Helicopter operations are increasing worldwide. If more active research and improvements are not conducted to improve flight safety, the reliability of helicopters will inevitably decrease.

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