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The Consequences and Recurrence of Dangerous Occurrences in Air Transport in 1919-2018

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Abstract

The paper presents statistical research results regarding the occurrence of which dangerous aviation events in in 1919-2018. The source of the information about the events was the AviationSafetyNetwork website. With the use of Excel 2016 and Statistica v. 12 computer programs, five time intervals were identified in which hazardous aviation incidents took place.
Characterizing the distribution of these events in all periods, due to the technological advancement and capabilities of airplanes, the distribution of dangerous events in the last three periods was compared. The following tests were used to verify the statistical hypotheses: $\chi2$, Shapiro-Wilk, Brown-Forsythe, Kruskal-Wallis. When choosing the appropriate test, the following factors were taken into account: the type of measurement scale, the dependence / independence of samples and their number. The standard significance level was assumed to be $\alpha = 0.05$. The consequences and repeatability of aviation events in the identified time intervals were analyzed. The research questions that were posed were the following: in which seasons of the year, months, days of the month and days of the week did the most dangerous events deaths occur? How often did dangerous events take place? Was the distribution of events similar in the identified periods?
The results of the conducted research allowed to identify five periods in which hazardous events took place and demonstrate that in particular periods the distribution of hazardous air events in subsequent seasons, months and days of the week was not the same.

Keywords

aviation accidents, air transport, recurrence occurrences, safety, statistics

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1. Introduction

Air transport significantly contributes to people's freedom of movement, employment, and goods flow. Despite the indisputable benefits associated with that, since the moment when a human being took off into the air, undesirable flight-related events (accidents, incidents) have occurred with varying intensity. With the development of air transport, efforts have been made to reduce their number. In Safety Management Manual (ICAO, 2012), the following periods of time are mentioned: the technical era - from the early 1900s until the late 1960s, the human factors era - from the early 1970s until the mid-1990s, and the organizational era - from the mid-1990s to the present day, during which various steps were taken to improve safety in air transport. This has been possible to achieve by increasing the reliability of aircraft (Kelly & Efthymiou, 2019; Airbus, 2018; Cichocki, 2017; Kozuba, 2014), the use of modern materials, improving airframes, cockpit instrumentation refinement, and increasing the reliability of engines. A better understanding of the human factor impact on the emergence of air accidents, as well as shaping the safety culture, have also played an important role (Syed, 2017; Marlinussen & Hunter, 2010; Moroney & Lilienthal, 2009; McFaden, 1996; Kortschot & Jamesion, 2019; Wrigley, 2018), while paying attention to multi-crew cooperation (MCC), personnel training, and the implementation of recommendations issued by committees appointed to explain accident causes. Consequently, in recent years, a flight on a commercial aircraft has been associated with low risk (Grant et al., 2018; Airbus, 2018; Boeing, 2016; Chen & Chang, 2011; Gill, 2009; Reason, 2009).

The improvement of air transport safety statistics (e.g. the number of accidents per one million take-offs or the number of fatalities per 100 million passengers) may be observed in the analyses of data presented in ICAO reports (ICAO, 2018, 2017, 2016) and in other studies (ATAG, 2018; Boeing, 2017; ATR, 2016; ATAG, 2016). The data included in the studies quoted so far (EASA, 2018, 2017) and on websites (https://www.ntsb.gov; https://www.skybrary.aero) are processed data. Their interpretation allows us to obtain a certain picture of accidents and incidents. The use of these data, however, in other studies is limited. Therefore, the authors have sought a source containing such data, allowing for greater freedom in performing statistical analyses. The https://aviation-safety.net/database/ website turned out to be such a source (This website also contains processed data). The selection of that particular website was determined both by the number of aviation occurrences it characterizes and the time interval it covers.

2. Information about the study

On the basis of the data presented in tabular form in *AviationSafetyNetwork*, and following additional operations performed in MS Excel, a table was prepared containing data on aviation safety occurrences that took place in 1919-2018. The rows represented successive safety occurrences, while the columns contain the following variables: year (1919, ..., 2018), month (January, ..., December), day of the month (1, ..., 31), day of the week (Monday, ..., Sunday), season (spring, ... , winter), consequences (fatalities / no fatalities), casualties (number of deaths), interval (number of days between successive occurrences - leap years were included).

Before the commencement of the analysis, the data collected were verified, and 459 rows were deleted as they did not contain all the information referring to the date of a given safety occurrence. In the years 1919-1929, four such occurrences were identified, in the years 1930-1939 - 13, in 1940-1949 - 83, in 1950-1959 - 27, in 1960-1969 - 49, in the years 1970-1979 - 81, in the years 1980-1989 - 81, in the years 1990-1999 - 68; in the years 2000-2009 - 38; in 2010-2018 - 15. Consequently, 21,172 cases were used in further analyses. The data prepared in MS Excel were then imported into the Statistica v 12 program, in which the main analyzes were conducted (Figure 1).

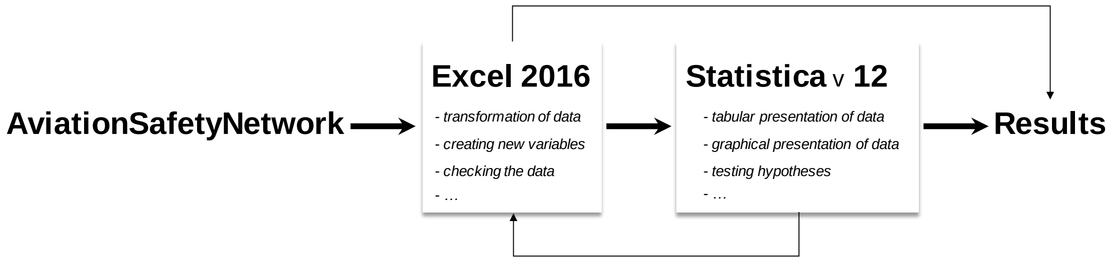

Figure 1. Using programs in data preparation and analysis. The authors' own work.

Taking into account the number of accidents and incidents in individual years and their distribution, five periods of time were specified (first 1919-1939, second 1939-1945, third 1946-1969, fourth 1970-1993, fifth 1994-2018) (Figure 2). It can be seen that the periods identified coincide to a large extent with steps being taken in order to increase safety (ICAO, 2018).

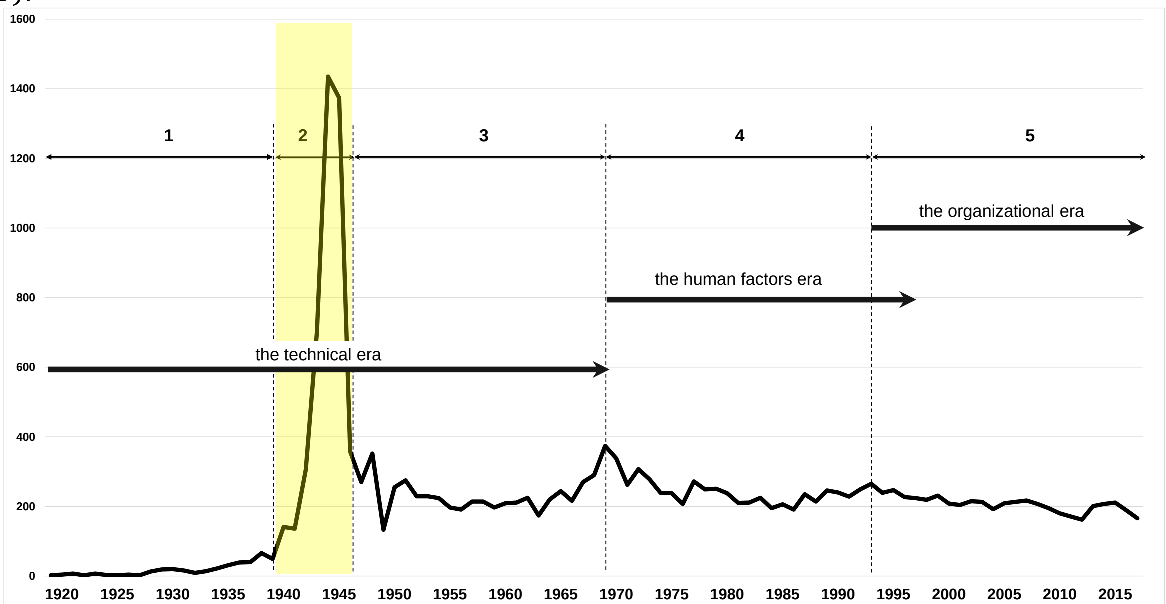

Figure 2. Characteristic periods of time related to flight safety occurrences in 1919-2018 (y-axis: number of events, x-axis: consecutive years). Source: the author's own study based on the data from https://aviation-safety.net/database/.

Even though attention was focused on the third, fourth, and fifth periods, occurrences that took place in 1919-1938 were also characterized. However, due to the state of technology and capabilities of aircraft, the data from that period were not taken into account in the comparisons. The years 1939-1945 were omitted in the analyses as, at that time, the destruction of aircraft was also caused by enemy action (Dzik, 2017).

Having collected the data, the authors looked for answers to the following questions in the context of the consequences of the safety occurrences: in which seasons, months, days of the month, and days of the week did the most occurrences take place, and when did the most people die? How many days passed between successive events? Was the distribution of occurrences similar within the periods identified? The following tests were used in order to verify statistical hypotheses: $\chi 2$, Shapiro-Wilk, Brown-Forsythe, Kruskal-Wallis. The selection of the respective test included the following: a measuring scale, dependence/independence of samples, and their number. If necessary, it was checked whether the assumption of variable distribution normality was met. The standard level of significance taken was $\alpha = 0.05$.

3. Results of the analyses

The years 1919-1938 was the period of air transport development. At that time, low travel comfort, lack of amenities at airports and high failure rates of aircraft which could carry a small number of passengers were not conducive to the development of this transport mode. Technological progress in the aviation industry (including the introduction of multi-engine aircraft) was a good impulse for changes (ATAG, 2018, 2016), leading to an increase in the interest in aircraft as a means of transport.

In the years 1919-1938, the number of safety occurrences increased systematically (two in 1919, 19 in 1929, 66 in 1938). Most of them (52.8%) had tragic consequences. Most frequently (9.4%), they were separated by two days. Most fatal occurrences took place in fall (34.7%) and on Tuesday (20.6%) - Figure 3.

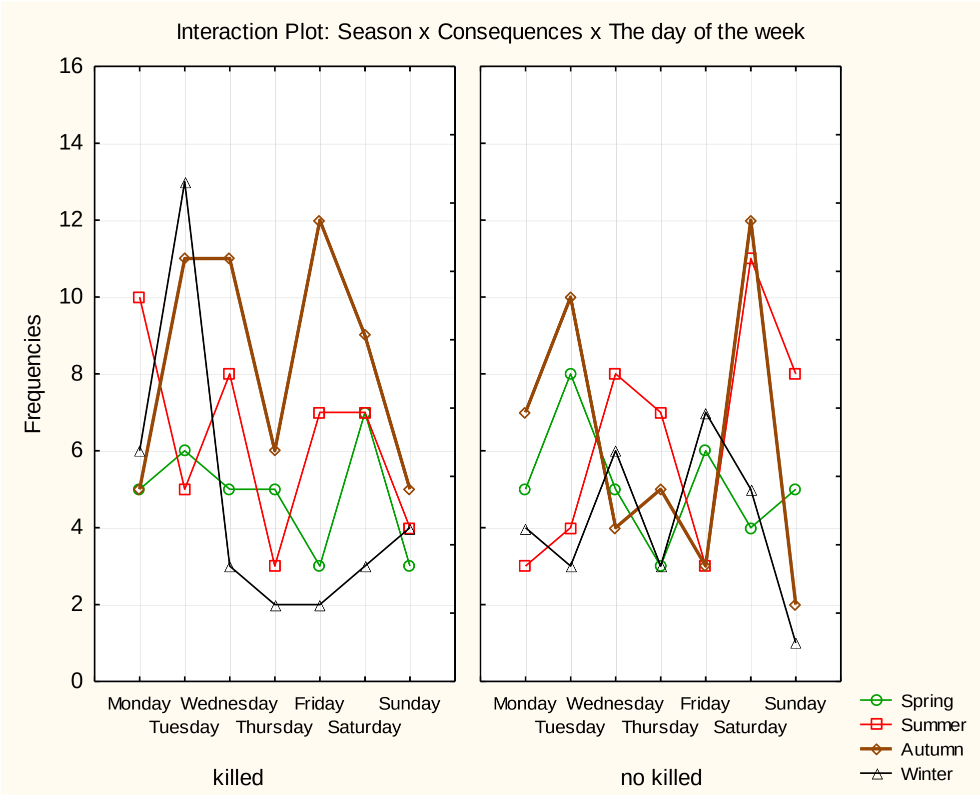

Figure 3. Air safety occurrence distribution in 1919-1939, taking into consideration their consequences, seasons and days of the week. Source: the authors' own study based on data from https://aviation-safety.net/database/.

In the period of time characterized, occurrences that did not lead to the death of crew or passengers most frequently took place in summer (29.0%). Most often, they took place on Saturdays (21.1%). Most of the individual incidents and accidents (9.2%) were separated by three days. In that period of time, a single accident most often involved three fatalities.

After the end of the war, the use of aircraft as a means of transport when road and rail infrastructure was damaged contributed to the development of air transport. Furthermore, the use of air transport became popular due to the development of tourism, increased equipment reliability, better comfort and shorter travel time, reduction of ticket prices, and - in the 1990s - the growing popularity of low-cost airlines and several other factors. Recently, other significant factors affecting this branch of transport are globalization, the development of the Internet, and the activities and experience of the new generation (ATAG, 2016).

While in the years 1919-1938, with the number of aviation safety occurrences systematically increasing, there were more involving fatalities. However, after World War II, the situation began to change (Cichocki, 2017; Dzik, 2017; Boeing, 2016; EASA, 2017). Although in the third period (1946-1969), safety occurrences leading to fatalities still prevailed slightly (50.8%). In the fourth period (1970-1993), the number of all safety occurrences increased in comparison with the third, because since the 1970s, a change in proportion with regard to the consequences has been clearly visible. Between 1970 and 1993, 56.3% of accidents did not result in fatalities. In subsequent years (1994-2018), this trend continued since the proportion of occurrences from this group - in the total number of air accidents and incidents - was even higher and amounted to 68.0%.

Therefore, the authors verified a hypothesis that an average number of fatal safety occurrences in aviation in individual periods (1946-1969), (1970-1993), (1994-2018) was the same. In order to assess the pattern of variation of a variable under consideration, the test for independent samples was used. Upon analyzing the results of the Shapiro-Wilk test, it was determined that the assumption of normality of the variable distribution in particular periods was not fulfilled. Because of that, the Kruskal-Wallis test was used to assess the variation in the average number of fatal accidents in successive periods. Considering the value of the test probability ($p = 0.000$), the hypothesis of the equality of the average number of fatal accidents in subsequent periods was rejected. The hypothesis assuming the equality of the average number of non-fatal aviation safety occurrences in the third, fourth, and fifth periods was verified in the same way. In that case, the distributions of the variable also deviated from the normal distribution. Based on the Kruskal-Wallis test results, it was concluded ($p = 0.009$) that the average number of non-fatal occurrences in subsequent periods was not identical. Differences in subsequent periods were illustrated using a box plot (Figure 4).

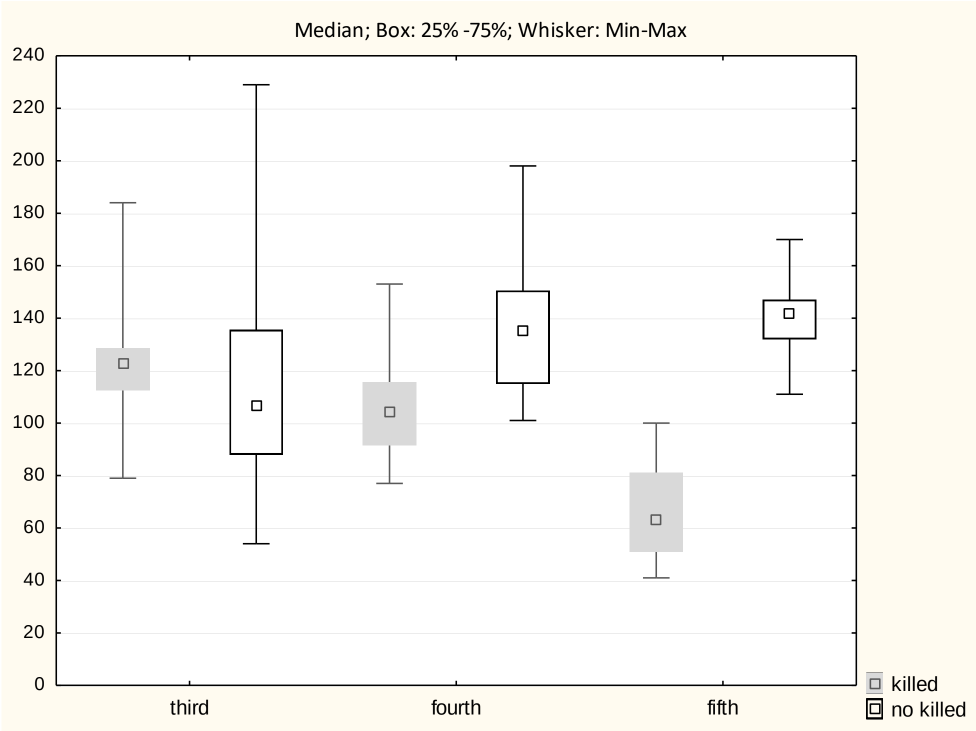

Figure 4. Box plot for fatal and non-fatal safety occurrences in successive periods (y-axis: number of events, x-axis: periods). Source: the authors' own study based on data from https://aviation-safety.net/database/.

Based on the distribution of incidents and accidents over particular year seasons, it was found that in the second half of the 1940s, in the 1950s, and 1960s, they occurred most frequently in winter, and least frequently in the spring months (spring 22.5%, summer 24.9%, fall 25.7%, winter 26.9%). An extensive range of the number of occurrences in particular seasons is characteristic for this period. In the 1970s, 1980s and the first half of the 1990s, the greatest number of aviation safety occurrences happened in summer (27.5%), and the least in the spring months (23.9%). In the remaining seasons, their number was similar (24.3% each). It is characteristic for the second half of the 1990s and the first and the second decade of the current century that the differences in the number of safety occurrences between seasons are not significant (spring 24.6%, summer 25.7%, fall 23.4%, winter 25.4%).

Similar to the situation when the distribution of safety occurrences was analyzed with regards to their consequences, the authors verified a hypothesis stating that the average number of aviation safety occurrences in spring (then summer, fall, and winter), in particular periods, was the same. While the assumption that distributions in particular periods were normal was rejected for spring, summer, and fall, the results of the Shapiro-Wilk test indicated that this assumption was met for winter. In this situation, the assumption of variance equality was verified, but it was not confirmed. Consequently, the Kruskal-Wallis test was used to verify the significance of differences. At the same time, the assumption of the equality of the average number of occurrences in spring, summer, fall, and winter in subsequent periods was rejected. Those differences have been presented in Figure 5.

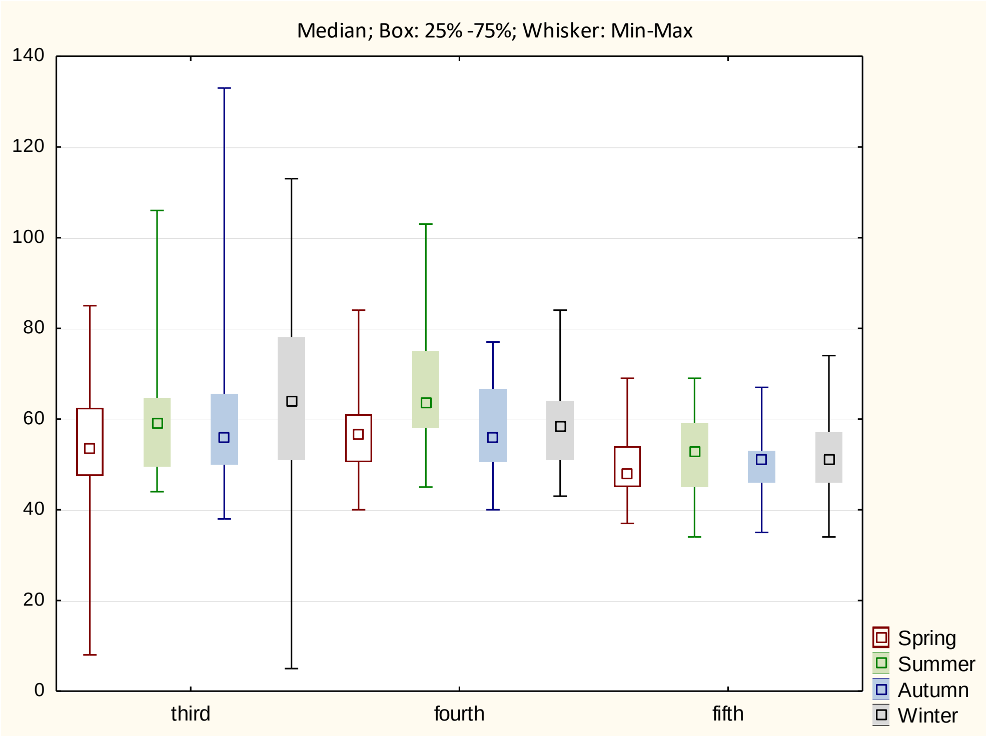

Figure 5. Box plot for occurrences taking place in particular periods and seasons (y-axis: number of events, x-axis: periods). Source: the authors' own study based on the data from https://aviation-safety.net/database/.

Therefore, it is not surprising that in the successive months, the number of aviation safety events was not identical. In general, they most often took place in December (9.3%), January (9.1%), and March (8.8%). The fewest of them occurred in February (7.4%), April (7.7%), and May (7.8%). Having taken the consequences of safety occurrences into consideration, it was determined that the number of those that were fatal increased, despite fluctuations, from January to December. A different tendency was noted when analyzing the distribution of non-fatal safety occurrences (statistically significant relationship ($p = 0.001$)). What is also characteristic is the fact that the number of fatal accidents, in subsequent periods and in all months, was decreasing. The same cannot be said of occurrences belonging to the second group, where the situation is different because - with the exception of July, August and September - in the remaining months, there were more of them than in the previous periods (Figure 6).

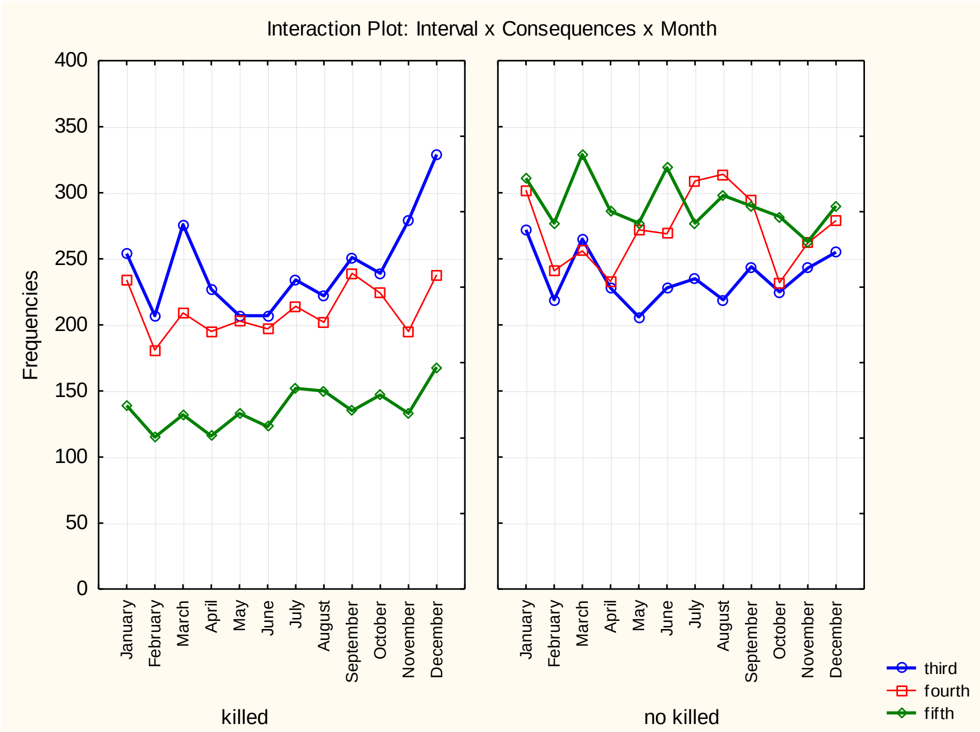

Figure 6. The distribution of occurrences over subsequent months, in 1946-2018. Source: the authors' own study based on data from https://aviation-safety.net/database/.

Seasonality rates and absolute seasonal variations were also calculated on the basis of the number of safety occurrences in particular months of 1946-1969, 1970-1993, 1994-2018. They show that, for example, in the period 1946-1969, due to the seasonal activity, the number of occurrences in January each year was higher than the monthly average by 9.4%, in March, by 12.5%, in September by 2.9%, in November by 8.5%, and in December by 21.4%. In the remaining months, the number of occurrences was lower by 11.4% in February, in April by 5.4%, in May by 14.1%, in June by 9.5%, in July by 2.5%, in August by 8.3%, and in October by 3.5% than the monthly average. The relative seasonal fluctuations of safety occurrences in particular periods are shown in Figure 7.

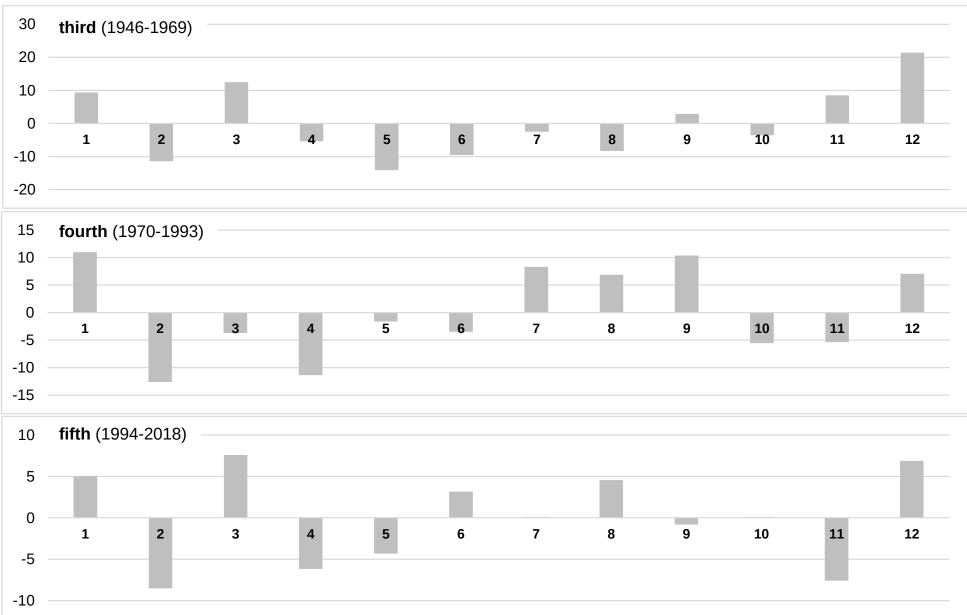

Figure 7. Relative seasonal fluctuations in the number of aviation safety occurrences in successive periods (y-axis: percentages, x-axis: next months). Source: the authors' own study based on data from https://aviation-safety.net/database/.

When analyzing the distribution of safety occurrences on the consecutive days of the month, it can be observed that they frequently took place at the beginning, in the middle and at the end of the month. In spring, these were the 10th (3.7%), 18th (3.5%), and 26th (3.6%) days of the month. In summer, the 9th (3.6%), 21st (3.8%), and 27th (4.0%). In the fall, the 12th (4.0%), 15th (4.1%), 19th (4.0%), and 22nd (4,0%). In winter, the 18th (4.1%), 21st (3.9%), and 28th (3.8%). The similarity of individual days of the month, taking into consideration the number of safety occurrences in the particular seasons, has been presented in Figure 8.

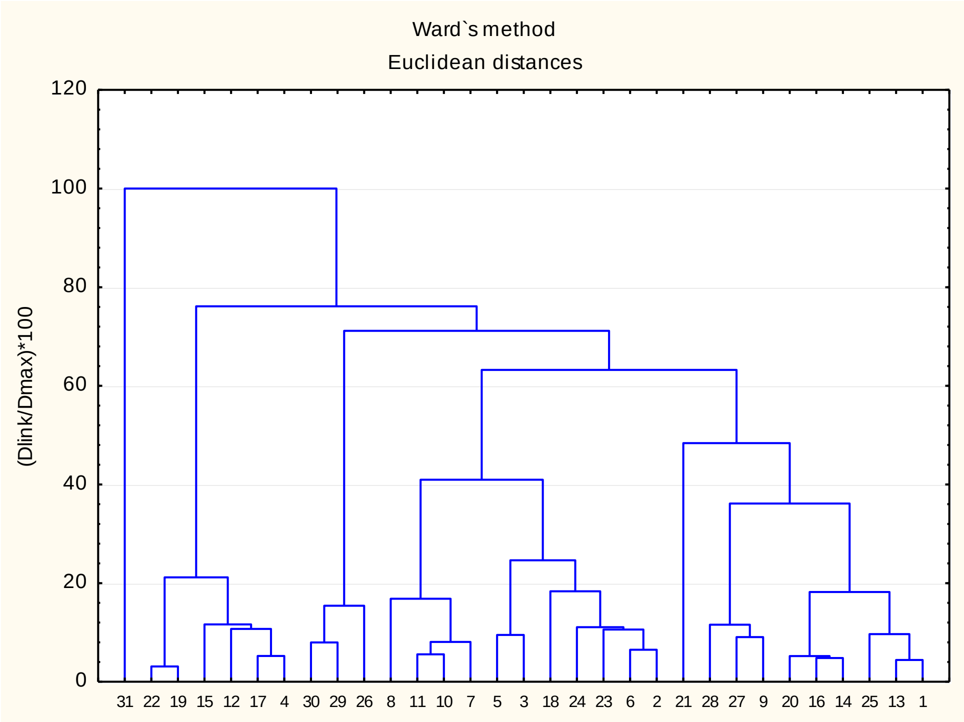

Figure 8. Dendrogram for days of the month, taking into consideration the number of safety occurrences in particular seasons (y-axis: binding distance, x-axis: subsequent months). Source: the authors' own study based on the data from https://aviation-safety.net/database/.

When viewing accidents and incidents in aviation from the perspective of individual days of the week, it was observed that there was a systematic increase in their number from Monday to Thursday (Monday 14.3%, Tuesday 14.8%, Wednesday 15.2%, Thursday 15.7%). On the subsequent days, their number decreased (Friday 15.4%, Saturday 13.3%, Sunday 11.3%).

The increase of the number of safety occurrences from Monday to Thursday and its decrease at the end of the week is visible both in the group of fatal accidents and in the group of safety occurrences that did not lead to fatalities (Figure 9).

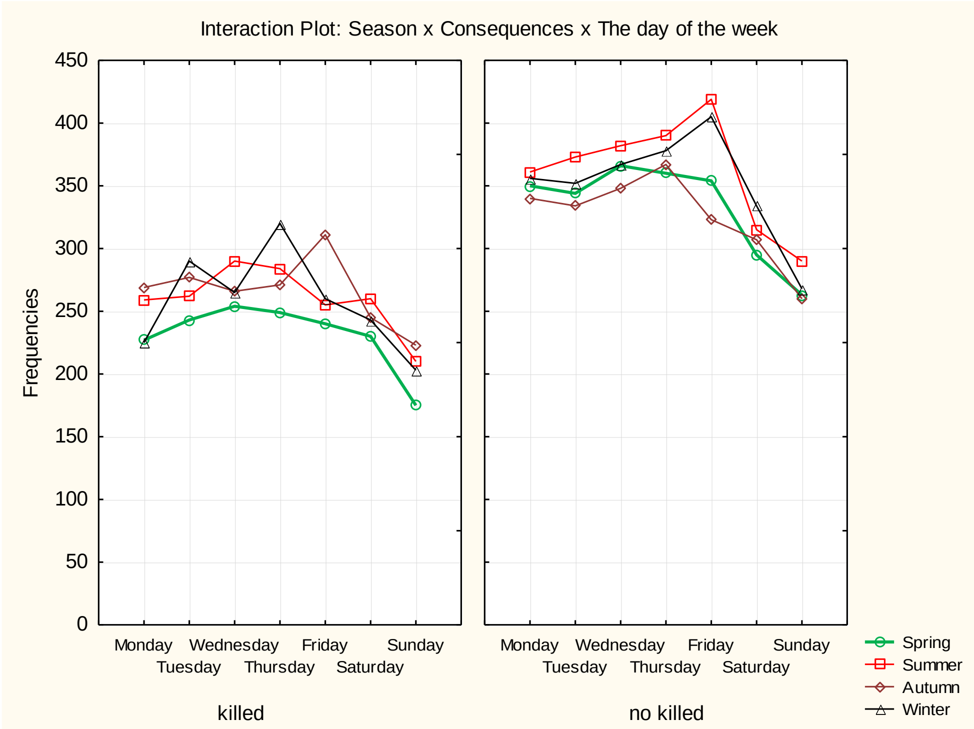

Figure 9. The distribution of occurrences over particular days of the week, in 1946-2018. Source: the authors' own study based on the data from https://aviation-safety.net/database/.

The frequency of accidents was also checked over the entire seventy-four years. They were more frequently separated by one day (31.6%) or happened on the same day (28.7% of all safety occurrences). It was determined that in successive periods, the number of safety occurrences that took place on the same day decreased (third period 30.7%, fourth 29.3%, fifth 26.5%). At the same time, they slightly increased among those separated by two days (third period 17.3%, fourth 18.4%, fifth 18.6%) or three days (third period 8.6%, fourth 8.8%, fifth 11.2%). In the group of occurrences which took place on the same day, regardless of the day of the week, the number of occurrences was usually two. There were also days on which there were more than ten of such occurrences (e.g., 19 in September, 1989).

While adverse occurrences have taken place throughout the history of aviation, as a result of the development of aircraft and the increase in the number of passengers carried by them, fatal accidents result in numerous fatalities. The authors verified a hypothesis that the average number of casualties per one accident was the same in successive periods. Because the distribution of the variable in subsequent periods was not normal, the Kruskal-Wallis test was used to assess its diversification. Considering the value of the test probability ($p = 0.000$), the above-mentioned hypothesis was rejected. The differences have been presented in Figure 10.

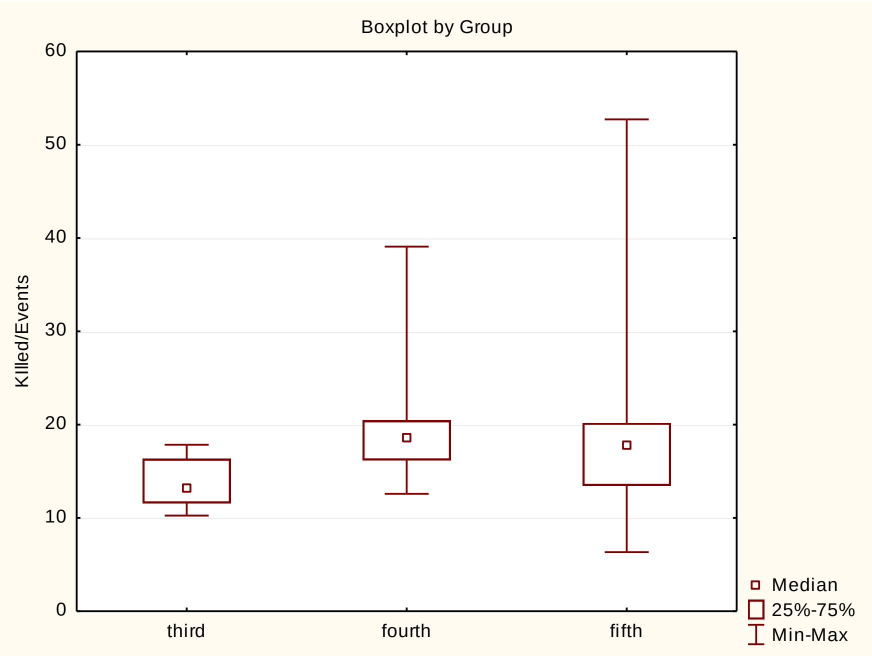

Figure 10. Box plot for average number of casualties per one accident, in individual periods /1946-2018/ (y-axis: number of victims / accident, x-axis: periods). Source: the authors' own study based on the data from https://aviation-safety.net/database/.

In 1946-2018, in spring, fall and winter, most occurrences resulted in two fatalities (14.1%, 11.9%, 12.9%, respectively). In the summer, there was most frequently one person dead (13.4%). As is apparent from the results obtained, in 1946-2018, in every season of the year, the number of safety occurrences in which one to ten people died was the highest (spring 69.2 %%, summer 66.7%, fall 68.2%, winter 61.1%). Most of the accidents involving at least 100 fatalities occurred in summer (3.2%) and the fewest in winter (2.6%).

4. Conclusions

Steps taken over the years to modernize airlines' fleets, improve the procedures, facilitate staff training, etc., have contributed to the improvement of air transport safety. However, new challenges are emerging, for example, in the field of training air personnel for flights with and without using automation, and an increase in the risk due to the more and more widespread use of modern onboard IT solutions (Lu, 2019; Ching-Fu & Shu-Chuan, 2012).

Information on safety occurrences may be obtained from government accident reports, operators, manufacturers, and information services. However, it is not easy to build a database that would contain information about all safety occurrences. Modern solutions in the transmission and collection of considerable amounts of data allow us to hope that it will be possible in the future. The data collected and analyzed by airlines have contributed to reducing the number of safety occurrences in aviation (Suajata et al., 2019; ATAG, 2018; Chen & Yu, 2018; Syed, 2017; ATAG, 2016; Kordian, 2010). This allows switching from a reactive mode (analysis of incidents based on flight crew reports) to a proactive mode (early detection of undesirable occurrences and implementing mitigation measures).

This study presents the results obtained based on data presented on the Aviation Safety Network website, which unfortunately do not cover all past safety occurrences. Considering the number of accidents and incidents, the situations that resulted in fatalities, and when the consequences were not so tragic, five characteristic time periods were distinguished in the years 1919-2018. While in the first period, the number of accidents in aviation increased, there was a significant increase in the second period. In the following periods, the number of fatal safety occurrences decreased while the number of non-fatal occurrences increased. In particular time periods, the number of safety occurrences in consecutive seasons, months, and days of the week was not the same. In the second half of the 1940s, the 1950s, and 1960s, accidents most frequently took place in winter, whereas the least frequently in spring months. In the 1970s, 1980s, and the first half of the 1990s, most aviation safety occurrences occurred in summer. In that period, the fewest of them also took place in the spring months. The second half of the 1990s and the present century has been when the difference in the number of occurrences between seasons is not significant. In 1946-2018, dangerous safety occurrences happened most often in December, January, and March. The fewest of them occurred in February, April, and May. Very often, they happened at the beginning, middle, and the end of the month. The increase in the number of safety occurrences could be observed from Monday to Thursday, and then their number decreased at the end of the week. More conclusions in this respect could be made by considering the information provided in the context of other data, e.g. the number of aircraft, number of passengers carried, the extent of aircraft use, and number of air operations performed in particular periods. It is worth noting that actions - e.g. taken by aviation authorities (on the national level by the CAA in Poland, on the regional level, EASA in Europe, and globally - by ICAO) in order to maintain an acceptable level of aviation safety, bring about desirable effects in the form of maintaining the number of undesirable occurrences at a similar level since 1975 (Figure 2). This is important because technological and material changes dynamically introduced to aircraft constructions did not cause such rapid growth in the level of aviation safety as it was the case at the turn of the 1970s, during the large scale introduction of jet engines, automation systems, etc.

Declaration of interest

The author/authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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