Analysis of Aviation Accident Trends and Safety Implications

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*Abstract*— **This paper provides an analytical review of aviation accident trends, aiming to enhance industry safety standards and guide passengers in making safer flight choices. The study meticulously compiles and examines data spanning several decades, focusing on the causality and survival rates of aviation accidents, with particular attention to the phase of flight and aircraft model-specific crash statistics. Through detailed visual and statistical analyses, we explore the interplay between aircraft age and accident rates, the influence of crash locations on survival outcomes, and the temporal distribution of accidents. Our results indicate a positive trend in safety improvements, as evidenced by the decrease in overall accident rates. Despite this progress, the data points to specific areas, such as certain flight phases and older aircraft models, where risks remain prevalent. These insights have significant implications for airlines in optimizing maintenance schedules to ensure timely service and for passengers in choosing flights judiciously. The study's outcomes are aimed at reinforcing safety protocols and informing policy initiatives within the aviation industry, thereby advancing the dual objectives of operational safety and efficiency.**

# Introduction

One of the most important aspects of modern global communication is air travel, which necessitates a constant dedication to safety. The rapid growth of the aviation business and improvements in technology make it even more important to carefully study accident patterns to improve safety measures. This study, "Analysis of Aviation Accident Trends and Safety Implications," is in response to the large amount of data that is becoming available about accidents, incidents, and safety measures. Utilizing the flight historical crash data and other related databases, our study aims to provide an in-depth look at past incidents and accidents to learn more about flight safety.

The primary goal of this research is to employ a data-centric approach, utilizing data visualizations and identifying the patterns and characteristics of aviation accidents. We analyzed the Aviation Accident Trends and Safety Implications data from Kaggle. Our investigation delves into dimensions such as accident frequency, severity, contributing factors, involved aircraft types, and the effectiveness of safety protocols. By extracting empirical evidence from the dataset, we aspire to present a clear understanding of the dynamics influencing aviation safety. The application of advanced analytics will be central to unraveling correlations, identifying risk factors, and proposing safety implications.

To achieve these goals, we adopt a multi-faceted approach that includes line charts, bar charts, combined charts, and tree maps among other visualization types. Our methodology encompasses diverse analytical techniques, including data cleaning in R, visual representations of charts in Tableau. This multi-faceted approach aims to offer a comprehensive and insightful evaluation of aviation accident trends. This research seeks to be a valuable resource for aviation safety professionals, policymakers, researchers, and industry stakeholders. By illuminating patterns and implications of aviation accidents, we anticipate contributing not only to academic discourse but also providing a practical guide for shaping future safety strategies and policies within the aviation domain. The findings of this study are expected to foster a safer and more resilient aviation ecosystem, influencing both research and practical considerations in aviation safety.

# Literature Review

This paper skillfully explores aspects including the frequency, severity, contributing variables, types of aircraft involved, and the effectiveness of safety procedures concerning accidents. The study's potential influence on aviation stakeholders highlights its importance, making it a useful tool for safety experts. Utilizing information from databases such as the Aviation Safety Reporting System we tend to apply an advanced data-centric methodology and visualization strategies to thoroughly investigate past occurrences and mishaps.

In a research, Clinton V. Oster Jr., John S. Strong, and C. Kurt Zorn examine the safety records of commercial passenger aircraft in the United States and abroad and evaluate the economic literature on aviation safety. The study highlights new problems and difficulties in airline safety as well as aviation security as a developing aspect of safety. The results highlight the necessity of a systems-based, proactive, and predictive approach to handle the upcoming wave of safety issues. Moving away from a reactive, incident-based strategy, the authors push for the development and comprehension of new types of data to improve safety across many areas of commercial aviation.

If we investigate another study by Nadine Muecklich, Ivan Sikora, Alexandros Paraskevas, and Anil Padhra, aviation safety and reliability are highlighted. This study studies aviation safety literature from 1984 to 2021, focusing on Normal Accident Theory (NAT), High-reliability Theory (HRT), and Resilience Engineering. This systematic scoping review (SSR) evaluates these three approaches to safety, specifically aircraft accidents. The study thoroughly examines NAT, HRT, and RE theories as they relate to aviation safety, providing useful insights into multiple viewpoints on aviation safety and reliability.

Statistical analysis has been utilized by other researchers to look at the data related to aviation accidents. For instance, Markus Hofmann and Darren Kerfoot applied a classification model to the problem of identifying fatal aircraft accidents/incidents based on flight information such as aircraft attributes, geographical attributes, and purpose of flight, etc. By implementing the CRISP-DM methodology. This procedure supports a business goal that involves using the predictive model to find characteristics that can be used to identify aircraft mishaps or accidents that result in fatalities.

Researchers utilize data visualization tools in addition to statistical analysis to analyze cricket performance. Cengiz Turkoglu and Jennifer Insley analyzed Aircraft Maintenance-Related Accidents and Serious Incidents, which focus on high-risk aviation areas and continue to cause accidents and serious incidents in the commercial air transport industry. They collected a dataset of maintenance-related accidents and major occurrences and used theme analysis to qualitatively analyze it. The paper examines modern CAT accidents and serious events from a maintenance perspective.

To learn more about analysis and prevention, other researchers conducted analyses on aviation safety, accident investigation, analysis, and prevention. They discovered that the USA has an annual financial cost of up to $4.64 billion due to incidents involving the latter. Although there has been a slight decline in the number of fatal aviation accidents over the past ten years, there is still a significant divide between general aviation and air carriers. They aim to include technology and aircraft design in all facets of aviation safety, accident prevention, and investigations.

# Methodology

1. Data collection: The aviation crash data, covering several decades, was sourced from Kaggle, an open-source data platform known for its comprehensive datasets. The dataset included detailed records of aviation incidents worldwide, with variables like date and time of crash, aircraft model, phase of flight, cause of the crash, and location. The data was downloaded in a format compatible with data analysis tools, typically CSV or Excel, to facilitate easy access and manipulation.

2. Data cleaning and preparation: The dataset was loaded into R, where initial data cleaning focused on removing null values and standardizing time data using the lubridate library. Data from 1960 to 2022 was specifically filtered to ensure a comprehensive analysis over a period significant for aviation changes. Efforts were made to avoid data bias, particularly in temporal distribution, ensuring a uniform representation across the selected years. The cleaned dataset was then exported in CSV format, suitable for analysis in Tableau.

3. Data visualization: Tableau was used for creating diverse visualizations of the aviation crash data. Key visualizations included bar plots, line graphs, treemaps, stacked bar charts, and dual-axis line-bar charts. These visualizations enabled the analysis of important variables like crash frequencies, trends over time, and detailed breakdowns by causes and locations. Interactive elements and filters were also incorporated, allowing for dynamic exploration of data based on different parameters such as time periods and geographic regions.

4. Data analysis: Within Tableau, quantitative analysis highlighted trends and correlations in aviation crash data, revealing critical insights into crash frequencies and their relationship with aircraft types and flight phases. Comparative analysis across different aircraft categories shed light on factors influencing crash outcomes.

5. Interpretation and conclusion: The data analysis culminated in a synthesis of key insights, with practical safety recommendations derived for industry and policy applications. The study's conclusions emphasized the need for ongoing improvements in aviation safety measures, supported by data-driven research. The importance of leveraging technology to enhance safety protocols and training programs was underscored, and the paper concluded with a call for further investigative efforts into predictive safety models.

# Result Analysis

## A. **Impact of Aircraft Age on Crash Causes and Fatality Rates**:

A graph showing a crash cause

Description automatically generated

On the provided butterfly chart, the average age of the flight (in years) is compared with average fatality rate (%) for various causes of airplane accidents. Based on the chart, the average fatality rate varies significantly based on the cause of the crash. There is a 68% fatality rate associated with terrorist acts, hijackings, and sabotage, followed by weather-related crashes at 65%, human factors at 58%. There is a 39% fatality rate due to other causes and technical failures, respectively.

The analysis shows that, older aircraft may have more technical problems, while the deadliest crashes are typically caused by intentional harm or weather. This information could be crucial for aviation safety and maintenance strategies, highlighting not only aircraft age but also flight operations and external factors that could affect aviation safety.

## B. **Aviation Accident Survival Rates by Location**:

A graph of a flight accident

Description automatically generated

In this bubble chart, each bubble represents the percentage of average survival rate from an airplane crash, whereas the horizontal axis identifies the location of the accident.

It is observed that accidents occurring near airport (less than 10kilometers from airport) have the highest survival rate, with an average survival rate of 60%, with a general decrease in survival rates as the crash site becomes farther from airport. Lakes, seas, oceans, rivers, plains, and valleys have moderate survival rates from 34% to 41%. Cities and mountains, with more remote and potentially challenging terrain, have significantly lower survival rates of 21% and 10%, respectively.

According to the visual data, bearing near airport resources, presumably including emergency services, may increase the chances of survival in an accident. On the other hand, crashes in more complex environments, such as cities or mountains, where immediate rescue may be more and more challenging, show significantly lower survival rate mainly near mountain where it is pretty tough to get medical help in such high-altitude regions.

Using this chart, aviation safety protocols and emergency response plans may be influenced by the importance of location in post-crash survival outcomes.

***C. Proportion of Aviation Accidents by Flight Type and Crash Site Location***

A graph of flight crash

Description automatically generated

In the stacked bar chart, each segment colored to represent a different crash site location, the stacked bar chart represents a comparison of the percentage of total airplane crash records versus the type of flight operations.

According to the bar chart, certain flight types are more likely to crash in specific locations. It is possible that the distribution of crash sites may reflect the inherent risks associated with the flight operations and the environments in which they are typically conducted.

In summary, the stacked bar chart provides a detailed breakdown of crash sites by flight type, highlighting the correlation between flight operations and crash locations. The data can assist in identifying high-risk areas for specific flight operations and informing safety protocols.

***D. Decades of Aviation Safety and Decline in Air Crash Incidents:***

***A graph showing a line of crash

Description automatically generated***

This line graph shows the trend of aircraft crashes from 1961 to approximately 2021.There was a peak in the number of crashes in the mid-1970s, followed by fluctuations, and then a general decline towards the end of the century and into the 21st century. After the year 2000, the trend continues to decline steadily, reaching its lowest point at the end of the timeline.

Observed results may indicate improvements in aviation safety, technological advancements, better regulation, or other factors contributing to the decrease in crash numbers. Post-2000, there was a sharp decline in international aviation crashes due to stricter international standards and practices.

***E. Peak Hours for Aviation Incidents/crashes:***

A graph of a flight crash

Description automatically generated

This line graph shows the relationship between the number of crashes and the time of day during which they occurred. The x-axis represents the 24-hour clock time, and the y-axis represents the number of crashes.

Each line fluctuates throughout the day, possibly indicating different datasets or categories. There’s significant peak in crash at the late morning to early afternoon hours. As a result of this peak in crashes, there is a notable drop in the late afternoon and evening hours, with the lowest crash rates usually occurring in the early morning hours. During daylight hours, air traffic volume is typically higher, so the frequency of crashes may be related to that. Additionally, several other factors, such as visibility, air traffic control workload, and pilot fatigue, may also contribute to this pattern.

As a result of this analysis, aviation safety authorities may be able to identify high-risk times for heightened monitoring and additional safety measures if needed.

A higher frequency of crashes occurred during the landing phase, particularly around 6 PM post-sunset, suggesting the challenges associated with evening landings.

***F.*** ***Aircraft Model-Related Crashes and Resulting Fatalities:***

A graph of crash

Description automatically generated

The line bar graph correlates the number of crashes to specific aircraft models. The x-axis categorizes different aircraft models, while the y-axis on the left indicates the number of crashes, represented by bars, and the y-axis on the right indicates the total fatalities, represented by a line. The bar graph shows that certain aircraft models are more likely to crash than others. There are peaks in the line graph at certain points, suggesting that certain aircraft models have disproportionately high fatalities.

The dual representation of data provides insight into not only the frequency of crashes per aircraft model but also the severity of those crashes in terms of fatalities. This information could be vital for safety analysts and aircraft manufacturers in addressing potential safety concerns related to specific aircraft models.

As a result of the dual presentation of data, we can both see the frequency of crashes for each aircraft model and the severity of those crashes based in the number of fatalities. For safety analysts and aircraft manufacturers, this information may be vital in addressing potential safety concerns.

***G. Crash Causation and Location Analysis:***

***A blue and green chart

Description automatically generated with medium confidence***

In the tree map, crash causes are categorized based on the location where the crash occurred. Each rectangle indicates how many records (crashes) exist within that category, the bigger the rectangle, the more crashes.

Many crashes appear to be caused by human factor near airports (less than 10 km away) as well as in plains and valleys, as indicated by the larger rectangles there.

In contrast, technical failure contributes to crashes across a wide range of environments, including airports, mountains, plains, valleys, bodies of water, and cities. Mountainous regions, however, see a particularly high proportion of crashes because of human factors. Other causes of crashes, such as bird strikes, structural failures, and weather-related crashes, are found to be significantly more prevalent near airports and in plains and valleys. The data set shows that terrorism, hijacking, and sabotage account for the least number of crashes, compared to technical failures and human factors.

Discussions

A comprehensive analysis of various datasets provides several critical insights. Despite the fact that older aircraft are more likely to experience technical failures, the most catastrophic accidents are often caused by factors other than age, such as weather and terrorism. Survival rates are significantly higher in areas near airports, emphasizing the importance of rapid emergency response.

A white airplane flying in the sky

Description automatically generatedA green airplane in the sky

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The bar-line chart indicates that the PZL-Mielec AN2 has been involved in numerous crashes but with a relatively low number of fatalities, which may be attributed to its smaller capacity, typically configured for single or dual occupancy. In contrast, the Boeing 737, a prevalent model in commercial aviation, has recorded fewer crashes yet a higher fatality count, reflecting its larger passenger capacity and the consequential impact of its accidents.

It has been shown that specific flight types are more susceptible to accidents in specific environments when crash locations are cross-referenced with flight operations. To accommodate the operational risks associated with various flight types, safety protocols need to be customized. There has been a commendable decline in the number of aviation crashes in the past six decades, likely due to advancements in aviation technology, regulatory improvements, and international safety standards.

It is evident from the distribution of crash causes by location that there are a variety of factors contributing to aviation accidents. Human factors and technical failures are prevalent in most locations, emphasizing the need for rigorous technical checks and continuous training. Several areas have experienced whether related crashes, suggesting that methodological considerations are crucial when planning and operating flights.

A higher level of monitoring and control could reduce crash risks during peak air traffic periods based on the correlation between incident timing and peak air traffic periods. In addition, some aircraft models are associated with higher crash and fatality rates, so safety reviews and interventions should be focused on those specific models.

As a result of the compilation of crash causes and locations, aviation accidents have become increasingly complex and multifactorial. In most cases, technical failures and human factors are to blame, particularly near airports and flat terrains, while terrorism is less common but equally severe.

In the future, the compiled findings from these analyses are expected to improve aviation safety. A strategic focus should be placed on areas such as rapid emergency response, operation-specific safety practices, peak period monitoring, and aircraft model safety evaluations. This insight could help reduce crash frequencies and increase survival rates, thus improving aviation safety protocols.

Conclusion

In summary, this thorough analysis of aviation accident trends and safety implications reveals positive safety improvements but identifies specific risk factors like certain flight phases and older aircraft models. The study, employing a data-centric approach and diverse analytical methods, contributes meaningful insights crucial for optimizing safety protocols in the aviation industry. The findings emphasize the need for continued vigilance, maintenance optimization, and informed flight decisions for both airlines and passengers. Acknowledging its limitations, the research calls for future exploration of broader datasets and additional variables. Overall, the study serves as a valuable resource for aviation safety professionals, policymakers, and researchers, shaping the future direction of safety strategies and policies in the aviation domain.

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[6] Analysis of Aviation Accident Trends and Safety Implication retrived from the link mentioned below <https://www.kaggle.com/datasets/rajsengo?resource=download&select=details.csv>