

Understanding Human Factors in Aviation Accidents: A Systematic Literature Review and Bibliometric Analysis

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Abstract

Human factors remain significant contributors to aviation accidents despite continued advances in aircraft technology, automation, and safety management systems. However, existing evidence remains fragmented across operational contexts, analytical frameworks, and methodological approaches. This study aimed to synthesize research on human factors in aviation accidents, identify dominant research themes and publication trends, examine methodological developments, and formulate future research directions. A systematic literature review based on the PRISMA 2020 framework was combined with bibliometric analysis. Scopus-indexed, English-language, open-access journal articles published between 2016 and 2026 were screened, resulting in 40 eligible studies from 668 initial records. Bibliometrix and VOSviewer were employed to analyze publication trends, author and country contributions, source distributions, citation patterns, and keyword co-occurrence networks, while thematic synthesis was conducted to interpret the findings. The results indicated increasing scholarly attention to human factors in aviation accidents, with China identified as the leading contributing country and aircraft accidents, aviation safety, human factors, and safety emerging as dominant research concepts. Five major themes were identified: pilot-related factors; organizational and operational factors; human-error analysis frameworks; emerging research trends; and future research priorities. The literature demonstrated a transition from descriptive accident investigation toward predictive approaches incorporating Human Factors Analysis and Classification System (HFACS), Bayesian networks, artificial intelligence, and machine learning. In conclusion, research on human factors in aviation accidents is becoming increasingly multidisciplinary and data-driven, requiring stronger integration of real-time data, organizational resilience, and human–technology interaction to enhance predictive and adaptive safety management.

INTRODUCTION

The aviation industry has achieved substantial improvements in safety performance over recent decades, supported by continuous advancements in aircraft technology, navigation systems, maintenance practices, regulatory oversight, and Safety Management Systems (SMS). These developments have significantly reduced accident rates and enhanced the reliability of commercial aviation operations. Nevertheless, aviation accidents and serious incidents continue to occur, often resulting in substantial human, operational, and economic consequences. Contemporary accident investigations consistently indicate that catastrophic aviation events rarely result from a single technical failure. Instead, accidents typically arise

from complex interactions among human operators, organizational conditions, environmental influences, and technological systems. Consequently, improving aviation safety requires not only technological innovation but also a comprehensive understanding of the human factors that influence operational performance throughout the aviation system.

Human factors have therefore become one of the most important research areas in aviation safety. Rather than referring solely to pilot error, human factors encompass the cognitive, psychological, physiological, organizational, and environmental conditions that influence human performance during aviation operations. Recent studies have demonstrated that aviation safety depends on interactions among multiple stakeholders, including pilots, air traffic controllers, maintenance engineers, flight dispatchers, and ground operations personnel. Organizational pressures have been shown to affect pilots' operational decision-making under adverse weather conditions, increasing the likelihood of unsafe actions (Casale et al., 2026). Similarly, communication failures and inadequate coordination among aviation professionals remain significant contributors to runway incursions and operational incidents (Yan et al., 2025). Beyond cockpit operations, maintenance-related human errors, inadequate documentation, and ineffective organizational communication have also been identified as important contributors to aviation safety risks (Bohrey & Chatpalliwar, 2024a; Zimmermann & Mendonca, 2021). These findings demonstrate that aviation accidents should be understood as systemic events shaped by interactions among individual performance, organizational processes, and operational environments.

The increasing recognition of human factors has stimulated significant developments in accident investigation methodologies. Among the most widely adopted analytical frameworks is the Human Factors Analysis and Classification System (HFACS), which classifies unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences contributing to accidents. Recent studies have expanded the application of HFACS by integrating Bayesian networks, neural networks, reinforcement learning, fuzzy logic, and complex network analysis to improve accident classification and safety prediction (Ahmadi et al., 2026; Harris & Li, 2019; Lyu et al., 2019; Wang et al., 2026; Zhou et al., 2018). These methodological developments demonstrate a transition from descriptive accident investigations toward predictive and data-driven approaches capable of identifying latent safety risks before accidents occur. Such advancements also illustrate how artificial intelligence and computational techniques increasingly support aviation safety management and accident prevention.

In addition to methodological advances, recent research has examined human factors across diverse operational contexts. Previous studies have investigated organizational pressure in helicopter accidents (Casale et al., 2026), controller-caused aviation accidents (Pan et al., 2025), flight crew coordination during unexpected operational events (Woltjer et al., 2026), pilot workload (Alaimo et al., 2020), fatigue risk management (Devine et al., 2025), maintenance operations (Bohrey & Chatpalliwar, 2024), ground operation incidents (Muecklich et al., 2023), accident patterns in Slovakia (Materna et al., 2025), and accident characteristics in Indonesia (Passarella & Nurmaini, 2022). Collectively, these studies have expanded understanding of human factors within aviation safety. However, the literature has become increasingly fragmented because many studies focus on specific accident cases, particular operational settings, or individual dimensions of human performance. Consequently, obtaining an integrated understanding of the dominant human factors contributing to aviation accidents across diverse operational contexts remains challenging.

Another notable development is the increasing adoption of computational approaches in aviation safety research. Artificial intelligence, machine learning, Bayesian modeling, fuzzy inference systems, and network analysis are increasingly employed to analyze accident reports, predict unsafe acts, and support safety decision-making (Ahmadi et al., 2026; Harris & Li,

2019). Although these approaches have enhanced analytical capabilities, previous studies have primarily focused on evaluating specific methods or algorithms rather than synthesizing how methodological developments collectively contribute to understanding human factors in aviation. Similarly, studies examining pilot behavior, fatigue, organizational pressure, maintenance performance, and accident investigation are generally conducted independently, resulting in limited integration between behavioral, organizational, and technological perspectives.

Although several review studies have examined aviation safety, general aviation accidents, and artificial intelligence applications, relatively few studies have systematically synthesized empirical evidence regarding the role of human factors in aviation accidents across different operational environments and methodological approaches. The absence of such synthesis limits understanding of dominant research themes, methodological evolution, and emerging trends within the field. Furthermore, the rapid growth of human factors research over the past decade highlights the need for a comprehensive review capable of integrating findings from diverse studies while identifying existing research gaps and future research directions.

Therefore, this study conducted a Systematic Literature Review (SLR) using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to synthesize studies on human factors in aviation accidents published between 2016 and 2026. Specifically, this review aimed to (1) identify the dominant human factors associated with aviation accidents, (2) classify the principal contributing factors examined in previous studies, (3) analyze publication trends and methodological developments in aviation human factors research, and (4) identify research gaps and future research opportunities. To complement the systematic review process, bibliometric analysis was employed to visualize publication patterns, research themes, and intellectual developments within the literature.

This study contributes to the aviation safety literature in several ways. First, it consolidates fragmented empirical evidence regarding the multidimensional role of human factors in aviation accidents. Second, it provides a comprehensive overview of methodological developments, particularly the integration of HFACS with artificial intelligence and advanced analytical techniques in accident investigation. Third, it identifies emerging research trends and unresolved issues that may guide future studies in aviation safety. Finally, the findings provide practical implications for airlines, maintenance organizations, aviation regulators, training institutions, and safety investigators by highlighting priority areas for improving human performance and strengthening accident prevention strategies. Through these contributions, this review supports the development of evidence-based aviation safety policies and advances future research on human factors within increasingly complex aviation systems.

METHOD

This study employed a Systematic Literature Review (SLR) to synthesize existing research on human factors in aviation accidents. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure a transparent and systematic selection process (Page et al., 2021). In addition, bibliometric analysis was conducted to examine publication trends, research themes, and the intellectual structure of the selected literature. The integration of systematic review and bibliometric approaches provided a comprehensive overview of the development of research on human factors in aviation accidents.

The literature search was conducted in July 2026 using the Scopus database. The search strategy employed keywords related to human factors and aviation accidents within the title, abstract, and keyword fields of publications. Eligibility criteria were established prior to the screening process. The review included English-language, open-access journal articles indexed

in Scopus and published between 2016 and 2026. Conference papers, book chapters, review articles, editorials, and studies unrelated to human factors in aviation accidents were excluded.

The literature selection process followed the PRISMA 2020 flow diagram. The initial search identified 668 records from the Scopus database. After applying predefined filters based on publication year, language, document type, source type, and accessibility, 75 articles remained for screening. Titles and abstracts were then reviewed according to the eligibility criteria, resulting in the exclusion of 35 articles that did not directly address human factors in aviation accidents. Consequently, 40 articles met all inclusion criteria and were included in the final review. The complete literature selection process is presented in Figure 1.

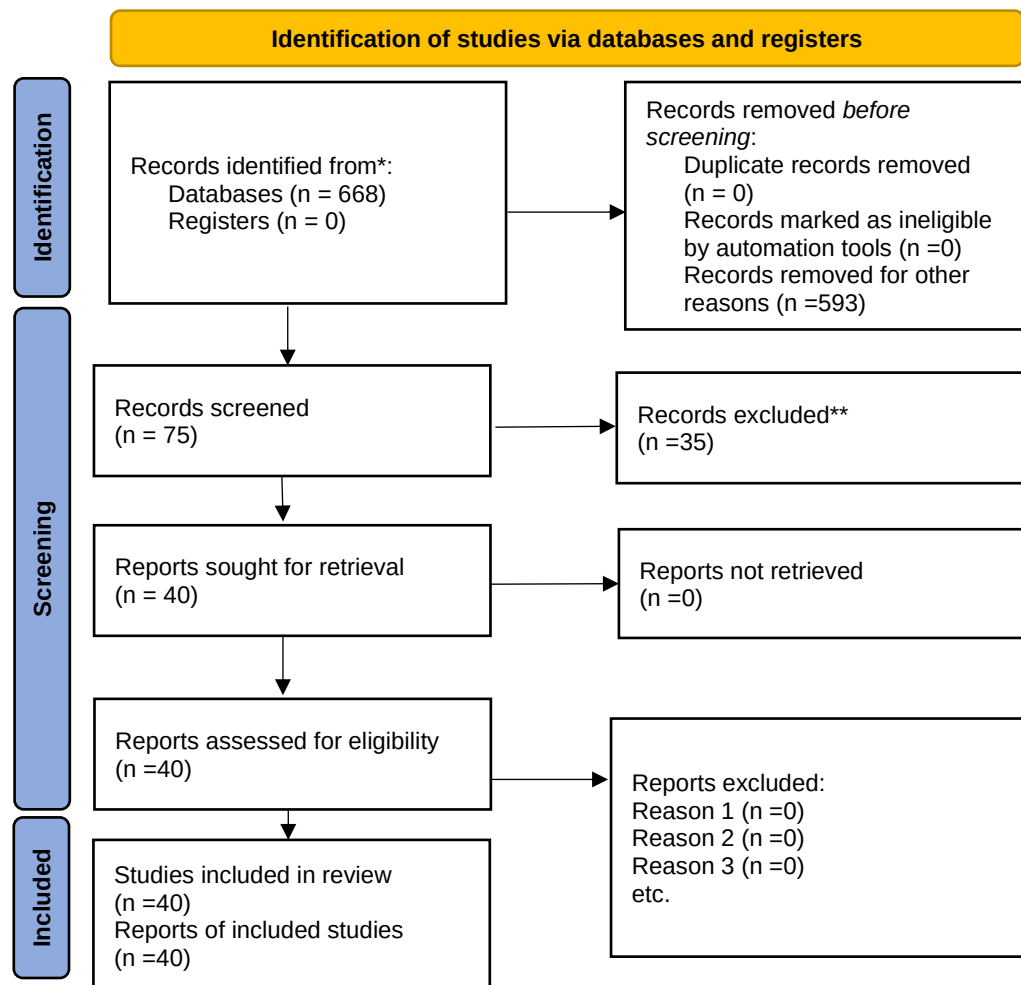


Figure 1. Prisma 2020 Flow Diagram of The Study Selection Process

Data from the selected articles were extracted using a standardized extraction form to ensure consistency throughout the review process. The extracted information included authors, publication year, journal, study country, research objectives, methods, analytical frameworks, investigated human-factor dimensions, and principal findings. The extracted data were then organized for thematic synthesis and bibliometric analysis.

Bibliometric analysis was conducted using Bibliometrix in RStudio and VOSviewer. Bibliometrix was used to analyze annual scientific production, source distribution, country contributions, and citation patterns, while VOSviewer was used to visualize keyword co-occurrence networks and thematic relationships among the selected publications. The bibliometric findings were further integrated with thematic synthesis to identify dominant

human factors, methodological developments, research trends, and future research directions in aviation accident studies.

RESULTS AND DISCUSSION

Author Production over Time

Tabel 1. Author Production Over Time

Author	Year	Freq	TC	TCpY
BOHREY OP	2024	2	11	3,667
CHAN WT-K	2023	1	14	3,5
CHAN WT-K	2025	1	4	2
CHATPALLIWAR AS	2024	2	11	3,667
FENG Y	2025	1	3	1,5
FENG Y	2026	1	0	0
GUO Y	2020	1	24	3,429
GUO Y	2024	1	1	0,333
LI W-C	2019	1	24	3
LI W-C	2023	1	14	3,5
LI W-C	2025	1	4	2
PASSARELLA R	2022	2	8	1,6
SIKORA I	2020	1	9	1,286
SIKORA I	2023	1	35	8,75
WANG M	2024	2	8	2,667
WANG Y	2021	1	14	2,333
WANG Y	2026	1	0	0

Table 1 presents the publication productivity of the most active authors in aviation human factors research during the period 2019–2026. The analysis indicates that research in this field is characterized by contributions from several recurring authors rather than being dominated by a single researcher. Among the most productive authors, Bohrey O.P., Chatpalliwar A.S., Passarella R., and Wang M. each published two articles, demonstrating consistent contributions to the development of aviation human factors research. Other authors, including Chan W.T.-K., Feng Y., Guo Y., Li W.-C., Sikora I., and Wang Y., also maintained research activity across different publication years, indicating sustained scholarly interest in this research area.

The temporal distribution further illustrates the evolution of research productivity over time. Initial contributions appeared in 2019 through the work of Li W.-C., followed by increasing publication activity in 2020 represented by Guo Y. and Sikora I. Research productivity continued to expand between 2021 and 2024, reflecting growing attention to aviation human factors, while publications in 2025–2026 indicate that the field remains active, particularly in studies examining predictive safety analysis, human reliability, and artificial intelligence applications.

Citation performance also varies among the most productive authors. Earlier publications generally accumulated higher citation counts than recently published studies, reflecting the longer period available for scholarly recognition. For example, the publications of Guo Y. and Li W.-C. received comparatively higher citation totals, indicating their substantial influence on subsequent aviation human factors research. Meanwhile, recently

published studies have begun to contribute to emerging research themes despite their relatively shorter citation window.

Overall, the author production analysis demonstrates that aviation human factors research has developed through the sustained contributions of multiple researchers rather than being concentrated within a small number of scholars. This pattern reflects the multidisciplinary character of the field, integrating aviation safety, human reliability, organizational behaviour, ergonomics, and computational modelling to address increasingly complex aviation safety challenges.

Country Scientific Production

Country Scientific Production

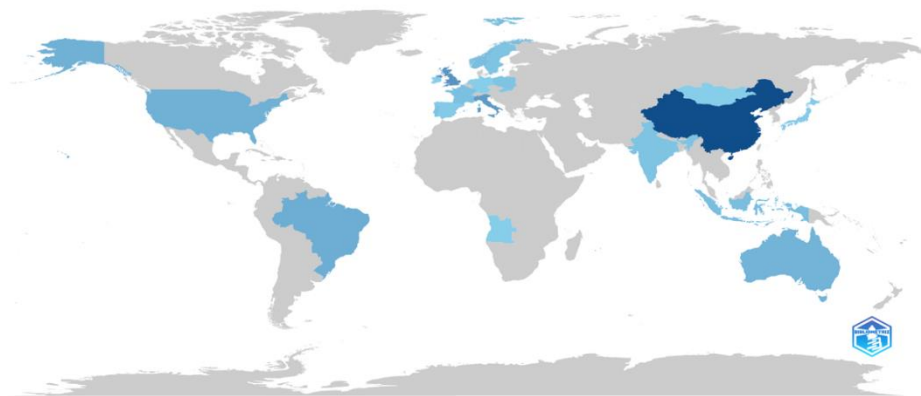


Figure 2. Country Scientific Production

Figure 2 illustrates the geographical distribution of scientific publications on human factors in aviation accidents. The results indicate that research in this field has been conducted across multiple regions worldwide, including Asia, Europe, North America, South America, and Oceania. However, publication productivity is unevenly distributed, with a small number of countries contributing a relatively larger proportion of the scientific output.

Among the contributing countries, China demonstrates the highest scientific production, as indicated by the darkest shading in Figure 3. This finding suggests that Chinese researchers have played a leading role in advancing aviation human factors research during the review period. The country's strong publication output reflects increasing academic interest in aviation safety, particularly in the application of advanced analytical approaches such as Human Factors Analysis and Classification System (HFACS), Bayesian Networks, artificial intelligence, and machine learning for accident investigation and safety assessment.

In addition to China, several countries also demonstrate notable research productivity, including the United States, Australia, India, the United Kingdom, Japan, Germany, Spain, Italy, Brazil, and Indonesia. Although their publication volumes are lower than China, these countries collectively contribute to the development of aviation human factors research through diverse research perspectives and operational contexts. Studies originating from these countries address a wide range of topics, including pilot decision-making, maintenance safety, air traffic management, organizational factors, accident investigation, and human reliability analysis.

The geographical distribution also reveals that research on aviation human factors is no longer concentrated exclusively in countries with large aviation industries. Emerging contributions from countries such as Indonesia, Brazil, and Slovakia indicate increasing international attention to aviation safety challenges in developing and transition economies. This expanding geographical coverage enriches the literature by providing evidence from

different regulatory systems, operational environments, and organizational contexts, thereby improving the generalizability of research findings.

Overall, the country scientific production analysis demonstrates that aviation human factors research has developed into a globally distributed research field. Nevertheless, the unequal distribution of publication output indicates that scientific contributions remain concentrated in several leading countries, particularly in Asia and developed aviation markets. This pattern provides opportunities for broader international collaboration and comparative studies to strengthen the global evidence base on human factors in aviation accident prevention.

Most Relevant Sources

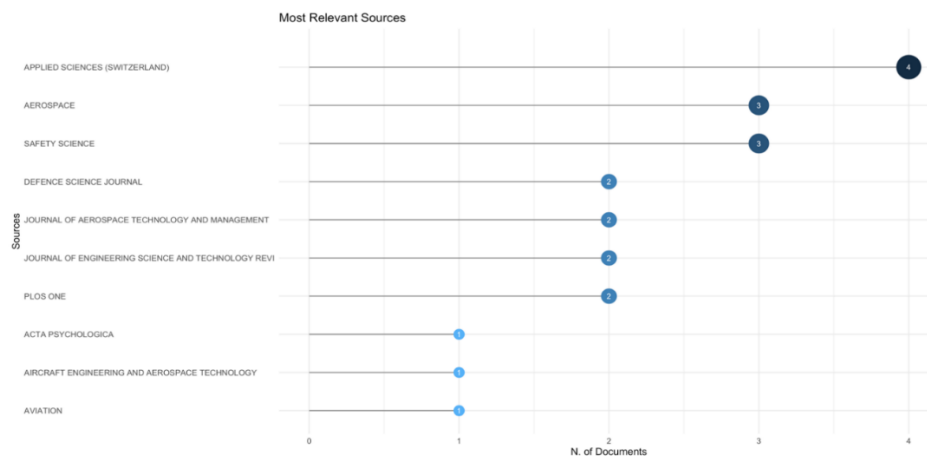


Figure 3. Most Relevant Sources

Figure 3 presents the distribution of the most relevant publication sources contributing to research on human factors in aviation accidents. The results indicate that the selected studies were published across a diverse range of journals, reflecting the multidisciplinary nature of aviation human factors research. The publications span several academic disciplines, including aviation, safety science, engineering, psychology, and transportation, demonstrating that the topic has attracted considerable attention from multiple research communities.

Among the indexed journals, Applied Sciences (Switzerland) published the largest number of articles within the reviewed dataset, contributing four publications. This finding suggests that the journal has become one of the primary publication outlets for research focusing on aviation safety, human reliability, and the application of computational methods in accident analysis. Following this, Aerospace and Safety Science each contributed three publications, indicating their important roles in disseminating studies related to aviation safety management, human factors, organizational safety, and accident prevention.

Several other journals, including Defence Science Journal, Journal of Aerospace Technology and Management, Journal of Engineering Science and Technology Review, and PLOS ONE, each published two articles related to the reviewed topic. These journals collectively illustrate the interdisciplinary development of aviation human factors research, covering topics such as human reliability assessment, aviation maintenance, flight operations, accident modelling, and safety management. Meanwhile, journals such as Acta Psychologica, Aircraft Engineering and Aerospace Technology, and Aviation each contributed one publication, further expanding the disciplinary diversity represented within the selected literature.

The distribution of publication sources also demonstrates that research on aviation human factors is not concentrated within a single specialized aviation journal. Instead, studies are disseminated through journals with different disciplinary orientations, including engineering, psychology, safety science, and applied sciences. This publication pattern reflects

the complex nature of aviation human factors, which requires the integration of technical, organizational, behavioural, and computational perspectives to better understand accident causation and safety performance.

Overall, the analysis of publication sources indicates that aviation human factors research has developed within a multidisciplinary scholarly environment. The diversity of journals represented in the reviewed literature suggests increasing collaboration among researchers from different scientific backgrounds and highlights the broad applicability of human factors research in supporting aviation safety, organizational resilience, and accident prevention.

Keyword Co-occurrence Network Analysis

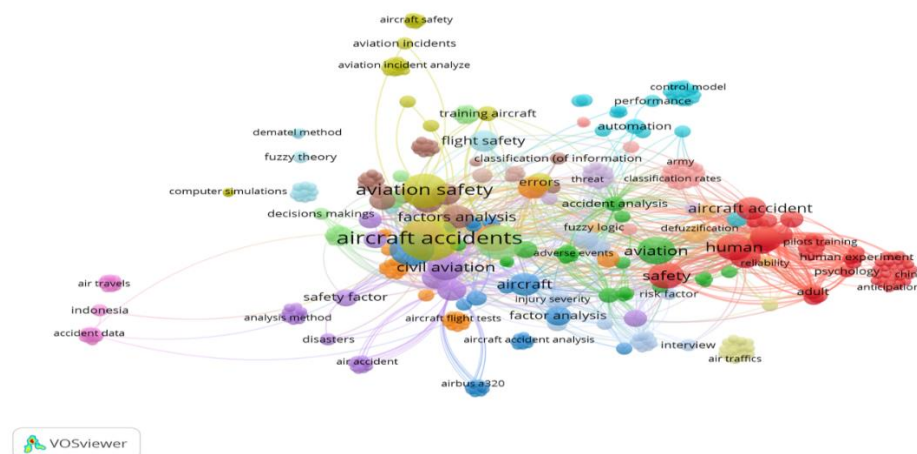


Figure 4. Keyword Co-occurrence Network Analysis

Figure 4 presents the keyword co-occurrence network generated using VOSviewer from the 40 selected publications. The visualization illustrates the conceptual structure of aviation human factors research by grouping frequently co-occurring keywords into interconnected thematic clusters. The size of each node represents the frequency of keyword occurrence, while the links between nodes indicate the strength of co-occurrence relationships within the literature.

The network reveals that “aircraft accidents,” “aviation safety,” “human,” “safety,” and “aviation” are the largest and most central nodes in the map, indicating that these keywords constitute the core concepts of the reviewed literature. Among these, “aircraft accidents” and “aviation safety” occupy central positions within the network and exhibit strong connections with numerous related terms, suggesting that accident prevention and safety management remain the primary focus of aviation human factors research.

Several thematic clusters can also be identified. One cluster centers on human and behavioural factors, including keywords such as human, psychology, human experiment, pilots training, adult, and anticipation, reflecting research that examines human performance, behavioural adaptation, and psychological aspects influencing aviation safety. Another cluster is dominated by aviation safety and accident analysis, connecting keywords such as aviation safety, aircraft accidents, flight safety, errors, accident analysis, and factors analysis. This cluster highlights the strong emphasis on identifying causal factors and improving accident investigation methodologies.

A third cluster is associated with automation and performance, where keywords such as automation, performance, and control model appear closely connected. This pattern indicates increasing research attention to the interaction between human operators and

automated systems in modern aviation environments. Additional clusters include topics related to civil aviation, aircraft, safety factors, and risk factors, illustrating the diversity of operational contexts investigated in the selected studies.

The network also identifies several specialized topics located at the periphery of the visualization. Keywords such as Indonesia, accident data, air travels, computer simulations, fuzzy theory, DEMATEL method, and aircraft safety appear less frequently but remain connected to the main research themes. Their peripheral position suggests that these topics represent more specific research contexts or methodological applications rather than the dominant themes within the literature.

Overall, the keyword co-occurrence network demonstrates that research on aviation human factors is organized around several interconnected themes rather than isolated topics. The strong relationships among keywords associated with accident investigation, human performance, aviation safety, organizational factors, automation, and risk analysis indicate that contemporary aviation safety research increasingly adopts an integrated socio-technical perspective to understand accident causation and improve safety performance.

Pilot-Related Human Factors

The thematic synthesis indicates that pilot-related human factors represent the most extensively investigated dimension within the aviation accident literature published between 2016 and 2026. Across the selected studies, pilot performance is consistently conceptualized as the outcome of interactions among cognitive processes, psychological conditions, operational demands, organizational influences, and technological systems rather than as the consequence of isolated human error. This finding reflects a substantial paradigm shift in aviation safety research, where accident causation is increasingly understood through a systems perspective that recognizes the interdependence between pilots and their operational environment.

One of the dominant themes concerns pilot decision-making under operational uncertainty. The reviewed studies demonstrate that decision-making is strongly influenced by training experience, operational complexity, and environmental conditions. Deshmukh and Majumdar (2025) reported that differences in pilots' training backgrounds influence how flight crews attribute operational events and safety occurrences, suggesting that professional training shapes risk perception and judgement beyond technical competence alone. Similarly, Yan et al. (2025). identified the stabilized approach, landing, and go-around phases as particularly vulnerable to human-factor-related incidents because pilots must continuously interpret changing operational conditions while making rapid decisions. These findings indicate that pilot decision-making should be understood as a dynamic cognitive process influenced by both professional preparation and operational context rather than as the consequence of isolated human error.

Another recurring finding concerns the influence of situational awareness, surprise, and automation interaction on flight safety. Gardini et al (2022) demonstrated that startle and surprise substantially affect pilots' cognitive processing during abnormal events, particularly when unexpected system behaviours reduce situational awareness. Similar evidence was reported by (Borghini et al., 2024), who showed that advanced warning systems designed to reduce flight upset events can improve pilot response by enhancing early hazard recognition and supporting more effective cognitive adaptation. These studies indicate that the increasing level of cockpit automation has not eliminated human factors; instead, it has transformed the nature of pilot performance by placing greater emphasis on monitoring, anticipation, and adaptive decision-making.

The literature also consistently identifies workload and fatigue as critical determinants of pilot performance. Alaimo et al. (2020) reported that increasing workload significantly

reduces cognitive capacity and operational performance, particularly during demanding phases of flight. Complementing this finding, Devine et al (2025) argued that fatigue should be managed through proactive Fatigue Risk Management Systems rather than reactive interventions following operational incidents. Together, these studies demonstrate that cognitive workload and physiological fatigue influence information processing, attention allocation, and judgement, thereby increasing the probability of operational errors when appropriate mitigation strategies are absent.

Recent studies further highlight the growing importance of behavioural and psychological characteristics in explaining pilot performance. Xu et al. (2026) found that defensive pessimism positively influences pilots' safety behaviour by encouraging greater anticipation of operational threats and more cautious decision-making. Likewise, Xiong et al. (2024) showed that variations in piloting behaviour during landing operations significantly affect operational risk, indicating that behavioural adaptation constitutes an important component of aviation safety. These findings suggest that pilot performance should be understood not only in terms of technical competence but also through behavioural strategies that enable pilots to anticipate and respond effectively to operational uncertainty.

An important methodological development emerging from the reviewed literature is the transition from descriptive accident investigation toward predictive assessment of pilot performance. Chen and Huang (2018) demonstrated that Bayesian Network modelling can effectively evaluate flight crew performance under uncertain operational conditions, while Ahrenbach & Goodloe, (2018) proposed formal logical approaches to identify pilot errors systematically. In addition, Sikora et al (2020) emphasized that contemporary analyses of loss-of-control-in-flight (LOC-I) accidents increasingly integrate behavioural models, crew resource management, and systems thinking to explain accident causation. Collectively, these methodological developments indicate that pilot-related human factors research is evolving from identifying accident causes after occurrence toward predicting unsafe operational conditions before accidents develop.

Overall, the reviewed studies consistently demonstrate that pilot-related human factors cannot be interpreted as isolated operational failures. Instead, pilot performance emerges through continuous interactions among organizational pressure, workload, fatigue, behavioural adaptation, automation, and operational complexity. This finding supports the contemporary systems perspective of aviation safety, which views accidents as products of interacting socio-technical processes rather than individual errors alone. Consequently, future research should further investigate how pilots interact with increasingly intelligent cockpit technologies and artificial intelligence to ensure that technological advancements strengthen, rather than diminish, human decision-making and operational resilience.

Organizational and Operational Human Factors

The thematic synthesis demonstrates that organizational and operational human factors constitute one of the most influential dimensions shaping aviation safety. Unlike traditional accident investigations that primarily attributed accidents to frontline operators, the reviewed studies consistently indicate that unsafe operational outcomes frequently originate from latent organizational conditions embedded within maintenance systems, operational management, communication processes, supervision, and safety culture. Consequently, contemporary aviation safety research increasingly recognizes that organizational deficiencies create the conditions under which unsafe human actions become more likely to occur. This finding reflects the growing adoption of a systems-based approach that interprets aviation accidents as the product of interactions among organizational structures, operational processes, technological systems, and human behaviour.

One of the most frequently investigated organizational issues concerns maintenance-related human factors. Several studies consistently report that maintenance errors rarely arise solely from individual negligence but are instead associated with organizational weaknesses such as inadequate supervision, incomplete maintenance documentation, ineffective communication, insufficient procedural compliance, and limited organizational learning. Bohrey and Chatpalliwar. (2024b) demonstrated that integrating the Human Factors Analysis and Classification System for Maintenance Extension (HFACS-ME) with Bayesian modelling enables a more comprehensive identification of latent organizational failures affecting maintenance performance. Similarly, Zimmermann and Mendonca (2021) emphasized that the quality of maintenance documentation significantly influences technicians' ability to perform maintenance activities accurately, thereby reducing the probability of operational failures. Complementing these findings, Lázaro et al (2024) showed through computer simulation modelling that organizational failures occurring during maintenance and operational processes propagate across multiple system components, reinforcing the importance of systematic organizational learning and preventive safety management. These findings suggest that maintenance safety depends not only on technical competence but also on organizational systems capable of supporting accurate information exchange and standardized maintenance practices.

The reviewed literature further highlights the strategic role of operational coordination in maintaining aviation safety. Zeng et al. (2024) identified flight dispatchers as critical decision-makers responsible for evaluating weather conditions, aircraft performance, flight planning, and operational risks before departure. Likewise, Muecklich et al. (2023) found that airport ground operation incidents frequently originate from communication failures, procedural deviations, and inadequate coordination among multiple operational actors. Similar conclusions were reported by Pan et al. (2025), who demonstrated that controller-caused aviation accidents are strongly associated with communication quality, workload, operational judgement, and supervisory practices within air traffic management systems. Collectively, these studies indicate that aviation safety depends upon effective interaction among pilots, dispatchers, air traffic controllers, maintenance personnel, and ground operation staff rather than on the performance of any single operational unit. Extending these findings, Nanyonga et al (2025) argued that strengthening organizational coordination across operational units is essential for improving aviation safety performance, particularly in rapidly developing aviation systems where institutional capacity, communication mechanisms, and organizational governance continue to evolve. Collectively, these studies indicate that aviation safety depends upon effective interaction among pilots, dispatchers, air traffic controllers, maintenance personnel, and ground operation staff rather than on the performance of any single operational unit.

This observation supports the broader conclusion presented by Stefana et al. (2024), who proposed that accident investigations should move beyond individual blame by adopting systemic approaches capable of identifying latent organizational conditions that influence unsafe behaviour. Similar perspectives are evident in studies examining accident patterns in Slovakia and Indonesia, where recurring accident characteristics were associated with broader organizational and institutional factors rather than isolated human errors (Materna et al., 2025; Passarella et al., 2022). These findings collectively reinforce the importance of organizational learning and safety culture as fundamental mechanisms for improving long-term aviation safety performance.

The reviewed studies also indicate that aviation organizations are increasingly implementing integrated human factors interventions to strengthen operational resilience. Research conducted by Harris and Li (2019) suggests that effective interventions require the simultaneous improvement of communication systems, maintenance procedures, operational

supervision, and safety training rather than isolated corrective actions. Likewise, several studies emphasize that organizational resilience depends upon continuous monitoring of operational performance, systematic reporting of safety issues, and proactive identification of emerging risks before accidents occur (Pan and Kong, 2026; Wang et al., 2026). These findings illustrate an important transition from reactive accident investigation toward proactive safety management supported by organizational learning and continuous performance improvement.

Overall, the reviewed literature demonstrates that organizational and operational human factors function as latent conditions shaping the performance of frontline aviation personnel. Rather than acting independently, organizational structures, maintenance systems, operational coordination, communication quality, and safety culture interact to influence human performance throughout aviation operations. This finding strengthens the systems perspective underlying contemporary aviation safety research and provides an important conceptual foundation for the subsequent development of analytical frameworks such as the Human Factors Analysis and Classification System (HFACS), which systematically classifies organizational influences, unsafe supervision, preconditions for unsafe acts, and unsafe acts within an integrated accident investigation framework. Accordingly, future research should further explore how digital transformation, organizational resilience, and human–technology collaboration can be integrated to support predictive aviation safety management in increasingly complex operational environments.

Human Error Analysis Frameworks

The thematic synthesis demonstrates that the development of human error analysis frameworks represents one of the most significant methodological trends in aviation human factors research during the period 2016–2026. While earlier accident investigations primarily relied on descriptive analyses of accident reports, recent studies increasingly employ structured analytical frameworks capable of identifying the relationships among unsafe acts, organizational influences, supervision, and environmental conditions. This evolution reflects a broader transition in aviation safety research from identifying accident causes after occurrence toward developing predictive approaches that support proactive safety management. Consequently, human error is no longer interpreted as an isolated event but as the outcome of multiple interacting factors operating across different organizational levels.

Among the reviewed studies, the Human Factors Analysis and Classification System (HFACS) remains the most frequently adopted framework for investigating aviation accidents. Building upon Reason's Swiss Cheese Model, HFACS enables researchers to classify accident causation into four interconnected levels: organizational influences, unsafe supervision, preconditions for unsafe acts, and unsafe acts. Several studies confirm the effectiveness of HFACS in identifying latent organizational conditions that contribute to operational failures. Lyu et al (2019) demonstrated that integrating HFACS with Bayesian Networks significantly improves the identification of causal relationships among contributing factors in air traffic safety. Similarly, Zhou et al. (2018) proposed a hybrid HFACS–Bayesian Network model that enhances accident analysis by quantifying probabilistic relationships among human factors. These findings suggest that HFACS provides a comprehensive conceptual structure for understanding accident causation while Bayesian modelling strengthens its analytical capability through probabilistic inference.

Recent methodological developments further extend HFACS through the integration of artificial intelligence and machine learning. Guo and Suo (2024) demonstrated that neural network models can accurately predict HFACS unsafe act classifications using historical accident data, thereby reducing subjectivity while improving the consistency of accident classification. More recently, Ahmadi et al., (2026) developed an automated HFACS classification model based on reinforcement learning, enabling more efficient processing of

aviation accident reports and enhancing classification reliability. Similarly, Guo et al. (2021). proposed a multi-head attention transformer model capable of predicting accident causes from aviation incident reports, illustrating the growing application of deep learning techniques in aviation safety analysis. Complementing these developments, Pan and Kong (2026) employed complex network analysis to examine the evolution of human factor risks in civil aviation operations, revealing that accident causation emerges from dynamic interactions among multiple risk factors rather than linear cause-and-effect relationships. Collectively, these studies indicate that computational intelligence has substantially expanded the analytical capability of traditional human factors frameworks.

Another important development concerns the application of Bayesian-based human reliability assessment in aviation safety. Wang et al. (2026) integrated Bayesian analysis with HFACS to evaluate human factors in flight testing, demonstrating that probabilistic modelling can identify critical operational risks before accidents occur. Chen and Huang (2018) similarly showed that Bayesian Network models effectively evaluate flight crew performance under uncertain operational conditions by estimating the likelihood of unsafe human behaviour. These findings illustrate that probabilistic approaches provide greater analytical flexibility than traditional descriptive investigations because they allow researchers to quantify uncertainty and evaluate the interaction among multiple operational variables simultaneously. Consequently, Bayesian modelling has become one of the most widely adopted complementary approaches within contemporary aviation human factors research.

Beyond methodological sophistication, the reviewed studies also reveal an important conceptual shift in the understanding of human error itself. Earlier accident investigations generally interpreted human error as the immediate cause of accidents, often focusing on the mistakes of pilots or operational personnel. In contrast, contemporary frameworks increasingly conceptualize human error as the manifestation of latent organizational conditions, inadequate supervision, communication failures, operational complexity, and environmental constraints. This systems-oriented perspective is consistently reflected across HFACS-based studies, Bayesian analyses, and network-based investigations, all of which emphasize that unsafe acts cannot be understood independently of the organizational systems within which they occur. Consequently, accident investigation has evolved from assigning responsibility to individual operators toward identifying opportunities for organizational learning and systemic risk reduction.

The methodological evolution identified in this review has important implications for future aviation safety research. The integration of HFACS with artificial intelligence, Bayesian inference, machine learning, and complex network analysis demonstrates a clear movement toward predictive safety management, in which accident risks are identified before operational failures occur. Nevertheless, several challenges remain. Most computational models continue to rely on historical accident databases and are rarely validated using real-time operational data. In addition, existing studies predominantly examine specific operational contexts, limiting the generalizability of their findings across different aviation sectors. Future research should therefore focus on integrating real-time flight data, human performance monitoring, and organizational safety indicators into unified analytical frameworks capable of supporting adaptive and predictive aviation safety management. Such developments would strengthen the role of human factors analysis not only as an accident investigation tool but also as a strategic component of proactive safety governance.

Emerging Research Trends in Aviation Human Factors

The thematic synthesis reveals a substantial transformation in the direction of aviation human factors research during the period 2016–2026. While earlier studies primarily focused on identifying the causes of aviation accidents through descriptive analyses of accident reports,

recent investigations increasingly emphasize predictive safety management supported by computational intelligence, advanced analytical models, and interdisciplinary approaches. This transition is consistent with the bibliometric findings, which indicate a growing concentration of publications on topics related to artificial intelligence, machine learning, Bayesian modelling, human reliability, and automation. These developments suggest that aviation human factors research is evolving from retrospective accident investigation toward proactive risk identification and safety prediction.

One of the most notable research trends is the integration of artificial intelligence (AI) into accident investigation and safety analysis. Traditional human factors analysis depended heavily on manual interpretation of accident reports, making the investigation process time-consuming and potentially subject to investigator bias. Recent studies have addressed these limitations by incorporating machine learning algorithms capable of automatically identifying patterns of unsafe behaviour from large accident databases. Harris and Li (2019) demonstrated that artificial neural networks can accurately classify unsafe acts within the Human Factors Analysis and Classification System (HFACS), while Ahmadi et al. (2026) further extended this capability by applying reinforcement learning to automate HFACS classification. These developments indicate that AI is increasingly used not to replace accident investigators but to enhance analytical efficiency and consistency in human factors assessment.

Another significant trend identified in this review is the increasing convergence between human factors research and organizational resilience. Several recent studies argue that future aviation safety cannot rely exclusively on technological advancement because the complexity of modern aviation systems requires stronger interaction between human capabilities and intelligent technologies. Nævestad et al. (2021) emphasize that resilient aviation organizations require adaptive safety governance, continuous organizational learning, and stronger institutional coordination to respond effectively to emerging operational risks. Similarly, Mínguez Barroso and Muñoz-Marrón (2023) argue that technological innovation should be accompanied by greater attention to psychological resilience and human cognitive adaptation, ensuring that advances in automation strengthen rather than weaken human performance. In addition, Szczepaniak et al. (2020) highlight that the rapid evolution of aviation technologies requires continuous evaluation of human-system interaction to maintain operational safety within increasingly complex socio-technical environments. Consequently, the emerging literature increasingly views pilots, maintenance personnel, dispatchers, and air traffic controllers as adaptive components within resilient socio-technical systems instead of isolated sources of operational error.

The reviewed literature also demonstrates increasing attention to human reliability assessment and predictive safety management. Wang et al. (2026) integrated human reliability analysis with Bayesian inference to assess flight safety under uncertain operational conditions, while Chen and Huang (2018) showed that probabilistic models can effectively estimate flight crew performance before operational failures occur. Unlike traditional post-accident investigations, these approaches aim to identify latent risks during routine operations, thereby supporting preventive decision-making within Safety Management Systems (SMS). This development reflects a broader transformation in aviation safety philosophy, where accident prevention increasingly depends on continuous monitoring, risk prediction, and organizational learning rather than solely on the analysis of completed accident investigations.

Another significant trend identified in this review is the increasing convergence between human factors research and organizational resilience. Several recent studies argue that future aviation safety cannot rely exclusively on technological advancement because the complexity of modern aviation systems requires stronger interaction between human capabilities and intelligent technologies. Research examining flight crew adaptation, organizational pressure, maintenance management, and human factors interventions

consistently emphasizes that technological innovation should strengthen human decision-making rather than replace it (Bohrey and Chatpalliwar, 2024b; Casale et al., 2026; Harris and Li, 2019; Woltjer et al., 2026). Consequently, the emerging literature increasingly views pilots, maintenance personnel, dispatchers, and air traffic controllers as adaptive components within resilient socio-technical systems instead of isolated sources of operational error.

Despite these important developments, several research gaps remain. Most computational approaches continue to rely on historical accident reports, limiting their ability to support real-time operational decision-making. Furthermore, empirical validation of AI-based human factors models across different countries and aviation sectors remains relatively limited. The reviewed studies also indicate that cross-country comparative analyses and longitudinal investigations remain underrepresented within the current literature. Future studies should therefore integrate operational flight data, organizational safety indicators, human performance monitoring, and artificial intelligence within unified analytical frameworks capable of supporting predictive and adaptive aviation safety management. Such integration would strengthen both the scientific understanding of human factors and the practical implementation of evidence-based safety strategies across increasingly complex aviation systems.

Future Research Agenda

The thematic synthesis of the reviewed studies suggests that aviation human factors research has experienced significant methodological and conceptual development over the past decade. Nevertheless, several important research gaps remain, indicating substantial opportunities for future investigation. Rather than focusing solely on identifying accident causes, future research should emphasize the development of predictive, adaptive, and evidence-based safety management systems capable of responding to the increasing complexity of contemporary aviation operations. Based on the synthesis of the selected studies, five major research agendas are proposed.

The first research agenda concerns the integration of artificial intelligence with established human factors frameworks. Although recent studies have successfully combined the Human Factors Analysis and Classification System (HFACS) with Bayesian Networks, neural networks, reinforcement learning, and complex network analysis (Ahmadi et al., 2026; Harris and Li, 2019; Lyu et al., 2019; Pan and Kong, 2026; Zhou et al., 2018), future developments should move beyond individual analytical models toward integrated intelligent decision-support systems.

Kourousis et al. (2018) emphasize that advances in computational modelling and human-centred analytical approaches provide opportunities to integrate organizational, operational, and cognitive dimensions within unified aviation safety frameworks. Likewise, Guo and Sun (2020) demonstrate that recent developments in intelligent analytical models can substantially improve the prediction of unsafe operational conditions, supporting the transition from reactive accident investigation toward predictive safety management. In addition, Chan et al. (2025) argue that future human factors research should increasingly utilize operational data collected during routine flight activities rather than relying exclusively on post-accident investigations. Such an approach would improve the ability of researchers and practitioners to detect emerging safety risks before accidents occur and strengthen evidence-based decision-making.

The second research agenda relates to the utilization of real-time operational and human performance data. Most of the reviewed studies rely primarily on historical accident reports and investigation databases. While these data provide valuable insights into accident causation, they are inherently retrospective and therefore limited in supporting proactive safety management. Future studies should incorporate operational flight data, cockpit monitoring

systems, physiological measurements, eye-tracking technology, wearable sensors, and other real-time performance indicators to better understand how workload, fatigue, situational awareness, and decision-making evolve during routine flight operations. The integration of real-time operational data would enable the development of predictive safety systems capable of identifying risks before accidents occur.

A third research priority involves the expansion of cross-country and cross-operational comparative studies. The reviewed literature includes studies conducted in several countries, including China, Indonesia, Slovakia, Brazil, and Sweden; however, most investigations remain limited to specific operational contexts or national accident databases. Consequently, the generalizability of current findings across different regulatory environments, organizational cultures, and aviation sectors remains uncertain. Comparative international studies would provide a more comprehensive understanding of how organizational structures, regulatory systems, and cultural factors influence the occurrence of human-factor-related accidents while also facilitating the development of globally applicable safety strategies.

The fourth research agenda concerns the evolving relationship between human operators and intelligent technologies. Current studies primarily investigate artificial intelligence as a tool for accident classification and safety analysis. However, considerably less attention has been devoted to understanding how pilots, maintenance personnel, air traffic controllers, and flight dispatchers interact with increasingly intelligent decision-support systems during operational activities. As cockpit automation and artificial intelligence continue to advance, future research should examine human–AI collaboration, trust in automation, adaptive decision-making, and shared cognitive systems to ensure that technological innovation enhances rather than diminishes human performance and operational resilience.

Finally, future research should further strengthen the organizational resilience perspective within aviation safety research. Although organizational pressure, maintenance management, communication, and safety culture have received increasing attention (Bohrey and Chatpalliwar, 2024a; Casale et al., 2026; Stefana et al., 2024), relatively few studies examine how aviation organizations continuously adapt to operational disruptions, technological change, and emerging safety threats. Integrating organizational resilience with human factors research would provide a more comprehensive understanding of how organizations anticipate, monitor, respond to, and learn from operational variability. Furthermore, Chan and Li (2023) argue that future aviation safety depends not only on identifying human factors but also on developing effective organizational interventions capable of translating human factors knowledge into practical safety management strategies. Accordingly, future research should place greater emphasis on evaluating the effectiveness of intervention programmes, organizational learning mechanisms, and evidence-based safety policies across different aviation contexts. Such an approach would support the transition from reactive accident investigation toward adaptive and resilient safety management systems.

CONCLUSION

This study systematically reviewed 40 Scopus-indexed journal articles published between 2016 and 2026 to synthesize the current state of research on human factors in aviation accidents. By integrating the PRISMA 2020 framework with bibliometric analysis and thematic synthesis, this review provided a comprehensive overview of publication trends, dominant research themes, methodological developments, and future research opportunities within the field.

The findings indicated that research on human factors in aviation had evolved considerably over the past decade. Bibliometric analysis revealed increasing scholarly attention to this topic, with publication activity distributed across multiple countries and multidisciplinary journals. The keyword co-occurrence network further showed that aircraft

accidents, aviation safety, human factors, and safety represented central concepts connecting the existing body of knowledge.

The thematic synthesis identified five major research themes. First, pilot-related human factors remained the most extensively investigated area, emphasizing decision-making, workload, fatigue, situational awareness, and behavioral adaptation. Second, organizational and operational human factors significantly influenced aviation safety through maintenance systems, communication practices, supervision, and organizational culture. Third, methodological developments increasingly integrated the Human Factors Analysis and Classification System (HFACS) with Bayesian networks, artificial intelligence, machine learning, and other computational approaches, reflecting a transition from descriptive accident investigation toward predictive safety analysis. Fourth, contemporary research demonstrated growing interest in organizational resilience, intelligent automation, and data-driven safety management. Finally, the review identified several future research priorities, including the integration of real-time operational data, cross-country comparative studies, human–AI collaboration, and adaptive safety management systems.

This review contributed to the aviation safety literature by consolidating fragmented evidence into an integrated conceptual understanding of human factors in aviation accidents. The findings also provided practical implications for aviation regulators, airlines, maintenance organizations, training institutions, and safety investigators by highlighting priority areas for strengthening accident prevention strategies and improving operational safety. Future research should adopt multidisciplinary and systems-oriented approaches that integrate behavioral science, organizational theory, artificial intelligence, and operational analytics to support safer and more resilient aviation systems.

REFERENCES

- Ahmadi, A., Sharif, S. S., & Banad, Y. M. (2026). Improving aviation safety analysis: Automated HFACS classification using reinforcement learning with group relative policy optimization. *Expert Systems with Applications*, 329.
- Ahrenbach, S., & Goodloe, A. (2018). Formal analysis of pilot error with agent safety logic. *Innovations in Systems and Software Engineering*, 14(1), 47–58.
- Alaimo, A., Esposito, A., Orlando, C., et al. (2020). Aircraft pilots workload analysis: Heart rate variability objective measures and NASA-Task Load Index subjective evaluation. *Aerospace*, 7(9).
- Bohrey, O. P., & Chatpalliwar, A. S. (2024a). Human error management in aviation maintenance using hybrid FMEA with a novel fuzzy approach. *Defence Science Journal*, 74(1), 11–21.
- Bohrey, O. P., & Chatpalliwar, A. S. (2024b). Modelling of human factors in aviation maintenance using HFACS-ME (Human Factors Analysis and Classification System—Maintenance Extension) and Bayesian network. *Defence Science Journal*, 74(5), 603–614.
- Borghini, G., Ronca, V., Giorgi, A., et al. (2024). Reducing flight upset risk and startle response: A study of the wake vortex alert with licensed commercial pilots. *Brain Research Bulletin*, 215.
- Casale, D. E., Silva, R. C. D., Ambrosio, D. R., et al. (2026). Organizational pressure and pilot decision-making in adverse weather: A naturalistic decision-making analysis of helicopter accidents. *Journal of Aerospace Technology and Management*, 18.
- Chan, W. T.-K., & Li, W.-C. (2023). Development of effective human factors interventions for aviation safety management. *Frontiers in Public Health*, 11.
- Chan, W. T.-K., Li, W.-C., & Braithwaite, G. (2025). Pilots' training backgrounds affecting the attribution of event causal factors and airline safety management. *Journal of Air*

Transport Management, 125.

- Chen, W., & Huang, S. (2018). Evaluating flight crew performance by a Bayesian network model. *Entropy*, 20(3).
- Deshmukh, R., & Majumdar, A. (2025). Visual flight rules stabilised approach: Identifying human-factor influences on incidents and accidents during stabilised approach, landing, and go-around flight phases for general aviation. *Applied Sciences*, 15(15).
- Devine, J. K., Choynowski, J., & Hursh, S. R. (2025). Evaluation of a biomathematical modeling software tool for the prediction of risk in flight schedules compared against incidence of fatigue reports. *Safety*, 11(1).
- Gardini, K. C., Chiavelli, F. H., Scarpari, J. R. S., et al. (2022). Conceptual models of startle, surprise and automation bias analyzed through recent aviation accident reports. *Journal of Aerospace Technology and Management*, 14.
- Guo, X., Chen, Y., Si, Q., et al. (2021). Evolution mechanism on the unsafe behavioural risks of general aviation pilots. *Engineering Economics*, 32(2), 104–117.
- Guo, Y., & Sun, Y. (2020). Flight safety assessment based on an integrated human reliability quantification approach. *PLOS ONE*, 15(4).
- Guo, Y., & Suo, X. (2024). Flight safety assessment based on a modified human error risk quantification approach. *PLOS ONE*, 19(4).
- Harris, D., & Li, W.-C. (2019). Using neural networks to predict HFACS unsafe acts from the pre-conditions of unsafe acts. *Ergonomics*, 62(2), 181–191.
- Kourousis, K. I., Chatzi, A. V., & Giannopoulos, I. K. (2018). The Airbus A320 family fan cowl door safety modification: A human factors scenario analysis. *Aircraft Engineering and Aerospace Technology*, 90(6), 967–972.
- Lázaro, F. L., Nogueira, R. P. R., Melicio, R., et al. (2024). Human factors as predictor of fatalities in aviation accidents: A neural network analysis. *Applied Sciences*, 14(2).
- Lyu, T., Song, W., & Du, K. (2019). Human factors analysis of air traffic safety based on HFACS-BN model. *Applied Sciences*, 9(23).
- Materna, M., Duricova, L., & Maternová, A. (2025). Patterns and causes of aviation accidents in Slovakia: A 17-year analysis. *Aerospace*, 12(8).
- Mínguez Barroso, C., & Muñoz-Marrón, D. (2023). Major air disasters: Accident investigation as a tool for defining eras in commercial aviation safety culture. *Aviation*, 27(2), 104–118.
- Muecklich, N., Sikora, I., Paraskevas, A., et al. (2023). The role of human factors in aviation ground operation-related accidents/incidents: A human error analysis approach. *Transportation Engineering*, 13.
- Nævestad, T.-O., Bye, R. J., Antonsen, S., et al. (2021). Examining the most accident-prone sector within commercial aviation: Why do accidents with light inland helicopters occur, and how can we improve safety? *Safety Science*, 139.
- Nanyonga, A., Wasswa, H., Joiner, K., et al. (2025). A multi-head attention-based transformer model for predicting causes in aviation incidents. *Modelling*, 6(2).
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *The BMJ*, 372.
- Pan, S., & Kong, L. (2026). Network analysis method for human factor risk evolution in civil aviation flights based on complex networks. *Journal of Engineering Science and Technology Review*, 19(2), 207–215.
- Pan, W., Li, Y., Jiang, Y., et al. (2025). Analysis of controller-caused aviation accidents based on association rule algorithm and Bayesian network. *Applied Sciences*, 15(17).
- Passarella, R., & Nurmaini, S. (2022). Data analysis investigation: Papua is the most unsafe province in Indonesia for aviation: An exploratory data analysis study from KNKT-database accidents and incidents (1988–2021). *Journal of Engineering Science and*

- Technology Review*, 15(3), 158–164.
- Passarella, R., Oktariani, G., Kurniawan, D., et al. (2022). Using the agglomerative hierarchical clustering method to examine human factors in Indonesian aviation accidents. *International Journal of Advanced Computer Science and Applications*, 13(9), 325–331.
- Sikora, I., Hari, B. L., & Hanusch, M. (2020). Human factors approaches and models in LOC-I accident analysis and prevention: Flight crew resource management techniques as a risk mitigation tool. *International Journal of Safety and Security Engineering*, 10(3), 301–310.
- Stefana, E., De Paola, E., Snaiderbaur Bono, C. S., et al. (2024). Beyond blame: A systemic accident analysis through a neutralized human factors taxonomy. *Human Factors and Ergonomics in Manufacturing and Service Industries*, 34(5), 450–465.