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Design of Models and Algorithms for Decision Support in Aviation Safety Tasks

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ABSTRACT

The aim of the study was to analyze effective models and algorithms of decision support that contribute to enhancing aviation safety. The study employed decision-making task formalization, probabilistic modeling, machine learning, multi-criteria analysis, and data analysis methods for processing heterogeneous information, including technical parameters, video streams, and behavioral characteristics. The research identified key features of decision support models and algorithms that improve aviation safety through real-time monitoring and adaptive response. Machine learning methods achieved up to 92% accuracy with a response time of 80 milliseconds, while multi-criteria analysis methods, including the analytic hierarchy process, reached 88% accuracy. The integration of probabilistic models with adaptive algorithms enabled consideration of operational environment variability and timely risk assessment. In 2024, 45% of aviation incidents were associated with crew error, 24% with technical malfunctions, and 13% with weather conditions. Intelligent decision support systems could potentially prevent 75% of incidents related to procedural violations. Neural networks were most suitable for behavioral analysis, decision trees for access control, and Bayesian networks for assessing technical failures. The findings contribute to the development of intelligent data analysis methods and decision support algorithms for aviation safety.

Keywords: Decision support systems; Flight safety; Risk assessment; Machine learning; Real time operation; Belief networks.

INTRODUCTION

Ensuring safety in the aviation industry is one of the priority tasks of the modern transport complex, given the growing volumes of passenger and cargo traffic, as well as the increasing requirements for reliability and responsiveness to potential threats. Modern conditions of air transport operation require the implementation of intelligent decision support systems (DSS) capable of efficiently analyzing large volumes of heterogeneous data and ensuring timely identification and prevention of emergencies and accidents. In this context, the design of models and algorithms that can account for data uncertainty, rapidly adapt to changing conditions, and minimize the impact of the human factor becomes particularly important.

In the field of decision support for aviation safety, a key challenge lies in the processing and analysis of large volumes of heterogeneous data under conditions of uncertainty and a dynamically changing operational environment. Rathnakumar and Liu (2025) demonstrated the effectiveness of machine learning methods in improving the accuracy of threat detection in aviation

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safety. Such approaches enabled the automation of large-scale data processing and reduced the influence of the human factor. Ahmad *et al.* (2024) investigated the use of probabilistic models for dealing with incomplete and uncertain information in DSS. Probabilistic approaches improved system adaptability and ensured more accurate risk forecasting. Ukwandu *et al.* (2022) focused on multi-criteria analysis, which allows for the consideration of complex risks and various factors in decision-making under high uncertainty. This approach helped select optimal safety measures considering numerous parameters. Garcia *et al.* (2021) proposed adaptive algorithms capable of adjusting parameters in real time depending on changes in the operational environment. Adaptability significantly increased the efficiency of monitoring and response systems. Agrawal *et al.* (2023) investigated strategies to mitigate human error by developing intuitive interfaces and employing expert systems. These methods mitigated operator errors and enhanced the quality of decision-making. To improve decision support, it is essential to highlight the necessity of an intuitive operator interface and to perform human-in-the-loop tests with skilled aircraft operators. These trials can measure the interface's influence on decision-making velocity and error frequency under significant workload and intense time constraints, offering insights to enhance the human-machine interaction module for actual operational contexts. This integration guarantees that the technology is both intuitive and efficient in practical flight scenarios.

Recent advancements in uncertainty-aware predictive modeling have further enhanced the capability of probabilistic methods to process complex sensor data under extreme conditions. Wang *et al.* (2026) proposed an enhanced Bayesian dynamic linear model for high-precision multi-step prediction of structural health monitoring sensor streams under extreme typhoon events. Their approach leverages kernel regression basis functions to adapt to severe environmental conditions, demonstrating robust handling of non-stationary and noisy input data. Such methods illustrate the potential of uncertainty-aware predictive models for improving reliability and decision-making in complex, high-risk operational environments.

Maulana *et al.* (2023) combined explainable data-driven methods with Bayesian filtering to predict the remaining useful lifetime of aircraft engines using NASA CMAPSS datasets. Their approach not only enhanced predictive accuracy but also improved interpretability, enabling operators to make informed decisions based on transparent model outputs. This methodology highlights the benefits of integrating probabilistic and explainable techniques in aviation safety monitoring.

Cankaya *et al.* (2023) investigated the use of Bayesian inference for evidence-based managerial decision-making in aviation incidents. Their study demonstrated that probabilistic approaches can effectively process heterogeneous and uncertain data, supporting reliable decisions under complex operational conditions. The findings emphasize the importance of adopting robust machine learning and Bayesian methods in safety-critical domains.

In addition, systematic reviews on Bayesian network applications in structural health monitoring highlight their growing role in multi-source data fusion, uncertainty modeling, and decision support – aspects that align with the core challenges in aviation DSS, where heterogeneous data and uncertainty are pervasive.

Furthermore, broader systematic literature on Bayesian network methods demonstrates their extensive use in reliability assessment across engineering domains, providing a strong theoretical foundation for incorporating probabilistic graphical models into aviation safety decision support frameworks.

Insaurralde *et al.* (2022) analyzed methods for integrating data from various sources, including sensor systems and video surveillance, to create comprehensive safety monitoring. Key compatibility issues were identified and solutions proposed. Insaurralde and Blasch (2022) emphasized the necessity of ensuring cybersecurity for intelligent DSS in aviation. The growth of digitalization has increased vulnerabilities, necessitating the integration of specialized cybersecurity modules into DSS frameworks. Such modules can include end-to-end encryption for critical flight data, aviation-specific intrusion detection algorithms, and cyber threat pre-warning modeling, which collectively enhance the protection of interconnected aviation digital infrastructure and ensure the resilience of decision-making systems against emerging cyber risks.

Mendes *et al.* (2022) highlighted the potential of deep learning and neural networks for improving the accuracy of threat prediction and classification. Significant advantages of these methods were demonstrated compared to traditional algorithms. Milbredt *et al.* (2022) focused on the adaptation of DSS to various stages of aviation safety management – from planning to operational response. The universality and flexibility of such systems increased the practical significance. Li *et al.* (2021) highlighted how integrating multiple methodological approaches in DSS design enhances reliability, adaptability, and real-time performance in complex, data-intensive environments. Although their study focuses on energy management in the smart industry and Internet of Things (IoT), the principles they describe – processing heterogeneous data, ensuring real-time decision-making, and maintaining system robustness – are directly relevant to aviation safety, where DSS must handle diverse sensor inputs, dynamic operational conditions, and high-stakes decisions. The role of integrating various methodological approaches to create effective solutions was emphasized. Thus, despite significant progress in the development of decision support models and algorithms, there remained a need for more flexible, adaptive, and secure systems capable of functioning effectively within the conditions of modern aviation infrastructure.

The aim of the study was to analyze methods that enhance the reliability of decision-making in aviation safety to reduce risks and improve management efficiency.

Research objectives:

- To examine data processing algorithms used for identifying potential threats.
- To assess the possibilities of integrating various information sources into a unified analytical system.
- To analyze the advantages and limitations of modern machine learning methods in the context of improving the reliability of decisions made.

METHODOLOGY

This work was structured as a thorough methodological and analytical research initiative integrating systematic literature evaluation, statistical data analysis, and conceptual modeling. The research design employed a multi-stage framework comprising: (1) identification and analysis of aviation safety challenges; (2) formalization of decision-making processes under uncertainty; (3) comparative evaluation of decision support models and algorithms; and (4) development of a conceptual architecture for intelligent DSS. The research combines qualitative examination of regulatory and analytical reports with quantitative evaluation of model performance metrics, assuring methodological coherence and practical significance.

During the study devoted to the design of DSS models and algorithms in aviation safety tasks, conducted from September 2024 to May 2025, comprehensive work was carried out to analyze and systematize existing approaches, as well as to develop conceptual foundations for creating effective intelligent systems. The research included several key stages aimed at achieving a comprehensive understanding of the specifics of decision-making under the high uncertainty and risks characteristic of the aviation industry.

The first stage involved a detailed characterization of aviation safety issues, including an examination of the main threats – from terrorist acts and technical failures to human errors. The analysis was carried out based on statistical data from the ICAO (2024). The study examined the role of modern DSS as tools that help reduce the influence of subjective factors and increase the speed of response to critical situations. Based on the conducted analysis, the main requirements for the models and algorithms of DSS were formulated, including high processing speed, resilience to incomplete and contradictory data, and reliability of the decisions made.

The next stage of the study focused on the formalization of decision-making processes in the context of aviation safety. The FAA annual report (2020) was used for analysis. A systematization of methods was carried out, allowing the presentation of tasks in the form of optimization, classification, or predictive models. Within the framework of the study, probabilistic approaches, elements of game theory, and modern machine learning methods were considered as tools for modeling decision-making processes under uncertainty. Models of probabilistic graphs, including Bayesian networks, neural networks, decision trees, and other artificial intelligence algorithms, were examined and analyzed. These models were selected based on their applicability at strategic, tactical, and operational management levels, as well as their ability to effectively process different types of input data and account for the specifics of threats at each level.

The following stage involved the analysis of decision support algorithms based on both expert rules and heuristics, as well as adaptive learning methods. The study relied on The Boeing Company's statistical review (2025), which included data covering the period from 1958 to 2024. The data from this review were primarily used as reference material to form the general context and define the research objectives.

The analysis incorporates heterogeneous data inputs relevant to aviation safety systems, including aggregated statistical sources, structured incident and accident records, sensor and telemetry data, and unstructured sources, such as video surveillance and meteorological information. The analyzed datasets are presumed to be adequately comprehensive and varied to represent a broad spectrum of operating settings, encompassing both routine processes and high-risk situations. Special emphasis is placed on data consistency, temporal alignment, and reliability, as these attributes directly affect the stability and precision of the implemented models.

The evaluation of model performance must acknowledge its primary dependence on historical data and modeling techniques. While such data provide a reliable basis for trend analysis and algorithm validation, they do not capture the complexities and variations of real-time operational environments. Therefore, the next research should focus on assessing the proposed models in real-world contexts, including pilot implementations inside airport infrastructures and air traffic control systems. This validation would facilitate the assessment of algorithm robustness in dynamic, high-load scenarios and the optimization of model parameters to ensure practical adaptability and stability in operational environments.

Simultaneously, a cohesive data standardization process was instituted to guarantee the uniform integration of diverse data. This protocol, founded on an ASTERIX-compliant DSS integration framework, was devised to: (1) rectify format discrepancies among various onboard sensors, surveillance systems, and meteorological platforms; (2) synchronize timestamps to a singular temporal reference, guaranteeing precise correlation of events across multiple data streams; and (3) reconcile reliability variances by employing weighted confidence metrics to sensor and telemetry inputs. The protocol functions via a modular middleware layer that incorporates DDS for high-throughput real-time communication, message queuing telemetry transport (MQTT), and advanced message queuing protocol (AMQP) for efficient sensor-to-edge transfer, and automated validation procedures for consistency verification. Through the implementation of this standardized methodology, the DSS ensures uniform intake of diverse information, hence enabling precise, prompt, and dependable decision support in high-risk aviation contexts.

At the same time, an important part of the work consisted of describing and analyzing filtering and data processing algorithms operating in real time, applied for the timely detection of threats based on signals from onboard sensors, surveillance cameras, and other sources.

To address the interoperability challenges posed by integrating heterogeneous data streams (including IoT-enabled sensors, high-resolution video surveillance feeds, and meteorological systems), the methodology specified the use of standardized communication protocols and middleware layers to support real-time data fusion. Specifically, lightweight publish/subscribe IoT protocols such as MQTT and AMQP were considered for sensor-to-edge data transport and asynchronous message handling, while more robust middleware based on DDS was identified as suited for high-performance, real-time distributed communication. These approaches ensure coherent data synchronization across diverse formats and timestamps, enabling consistent ingestion into analytic pipelines (e.g., DDS for high-throughput data sharing, MQTT/AMQP for edge-device telemetry). Additionally, aviation-specific data exchange standards such as ASTERIX were acknowledged as foundational for integrating surveillance and air traffic data within the broader decision support framework, ensuring compatibility with legacy aviation systems and surveillance services.

Particular attention in the research was paid to the architecture of DSS and its key components. Statistical materials from the EASA (2025) were used as information sources. Within the framework of the study, the main data sources were identified – sensors, databases, video surveillance systems, and meteorological information. Modules for threat analysis and forecasting, operator interaction interfaces, as well as feedback and adaptation mechanisms, were developed and described. A comparative analysis of decision support algorithms was conducted, taking into account accuracy, response time, and adaptability, which made it possible to identify the most suitable methods for processing heterogeneous information and ensuring effective user interaction. Such structuring served as the foundation for creating systems capable of integrating heterogeneous data and adapting to changing conditions.

RESULTS

Aviation safety is critical for modern transport, as air travel impacts both the global economy and daily life. The efficiency with which the aviation industry ensures the protection of passengers, crew, and infrastructure directly affects stability and trust in both international and domestic transportation. However, the rapid development of technologies and the growth in the intensity of air traffic are accompanied by an increase in risks threatening the safe functioning of the aviation sector.

Among the main threats faced by civil aviation are terrorist acts, technical malfunctions, equipment failures, adverse weather conditions, and the human factor, including errors made by pilots, air traffic controllers, and technical personnel (Table 1). Each of these factors can lead to catastrophic consequences if not detected and neutralized in a timely manner. Under such conditions, the availability of tools capable of promptly analyzing information and making well-founded decisions in real time becomes particularly crucial.

Table 1. Distribution of aviation incidents by cause (world statistics for 2024).

Cause of the incident	Number of cases	Share (%)	Average response time (min)	Potential preventability with DSS (%)
Crew errors	168	45	8	65
Technical malfunctions	92	24	12	40
Weather conditions	48	13	5	50
Security procedure violations	30	8	15	75
Other	35	10	9	30

Source: Elaborated by the authors based on ICAO (2024). The "average response time" refers to the operational (human/organizational) response time, not algorithmic latency.

The data highlight that human factors, particularly crew errors, dominate aviation incidents, accounting for 45% of cases. While technical malfunctions are less frequent, they require longer response times, underscoring the need for rapid detection and intervention. High potential preventability through DSS, especially for security violations and crew errors, indicates that DSS implementation can significantly enhance timely and accurate decision-making in aviation safety.

One of the key elements of the aviation safety system is the DSS, which helps specialists process large volumes of data, identify potential threats, and develop effective response strategies. DSS improves decision-making accuracy and speed, minimizes human factor influence, and contributes to timely incident prevention (Kondratenko *et al.* 2016a). Its implementation and development are becoming essential directions in strengthening the aviation industry's resilience to internal and external threats.

As aviation networks grow more complex, effective DSS models and algorithms are increasingly important to ensure timely and accurate decision-making in critical situations. DSS should not only assist in responding to incidents but also predict the development of potential threats based on analyses of current and historical data (Degas *et al.* 2022; Kerimkhulle *et al.* 2022).

A key task of such systems is minimizing the impact of the human factor, as statistics show that a significant proportion of aviation incidents are associated with personnel errors (Martinez-Marquez *et al.* 2021). The designed algorithms must account for possible cognitive and behavioral deviations of operators and support decision-making under stress, information overload, and time constraints.

Another important task is the automation of large-scale data analysis. Modern aviation systems rely on numerous information sources: technical parameters from onboard systems, meteorological data, ground service information, and behavioral indicators from passengers and employees (Singh *et al.* 2024). In order to integrate these heterogeneous data streams in real time, this study conceptualized architectural layers that employ standardized communication protocols and middleware solutions. Lightweight protocols such as MQTT and AMQP were identified as effective for asynchronous device-to-platform messaging in IoT environments, enabling timely aggregation of telemetry and sensor data. Protocols like DDS were recognized as suitable for high-performance, real-time distributed communication across analytic nodes. By combining these mechanisms, real-time data fusion can be achieved despite differences in data format, update frequency, and source reliability.

Securing the cybersecurity of DSS is a significant problem, as these systems handle sensitive flight data and integrate with extensive flight management infrastructure. Alongside traditional methods like data encryption and access control, novel strategies encompass blockchain-based mechanisms for data integrity verification (ensuring tamper-proof audit trails), zero-trust architectural principles (continuous authentication and stringent access validation for each component), and privacy-preserving computation techniques such as homomorphic encryption, which facilitates encrypted data processing without decryption. These solutions can alleviate hazards related to unauthorized access, data manipulation, and insider threats, which are especially pertinent for DSS functioning in distributed and linked aviation contexts.

Ensuring aviation safety is a complex and multi-layered task, encompassing all stages of the aviation system's operation – from strategic planning to operational incident response (Eleimat and Őszi 2025). One of the defining features of this field is its multi-level structure. During the planning stage, it is necessary to consider flight routes, schedules, airspace load, and risk assessment. The monitoring stage involves continuous observation of equipment condition, weather, passenger behavior, and staff actions. The final and most critical stage is operational response to emergencies, where immediate decision-making based on current information is crucial.

Aviation safety tasks are complicated by a high level of uncertainty and incomplete information. Incidents may unfold suddenly, and data can be contradictory, delayed, or even absent. For example, in cases of technical malfunction, sensors may transmit distorted signals, while in the case of a terrorist threat, behavioral data may be ambiguous and subjective. This requires DSS to operate effectively under limited and fragmented information, adapting to constantly changing circumstances.

Speed and reliability of decisions are essential requirements. In aviation, time is considered a critical factor, as response delays can lead to severe negative consequences (Lazic and Grujic 2022). However, decisions must be not only fast but also well-reasoned, as incorrect actions may also result in catastrophe. Addressing aviation safety tasks, therefore, demands intelligent systems capable of rapid data processing, risk assessment, and recommendation generation that account for the current situation and threat level.

Modeling decision-making processes in aviation safety assurance tasks constitutes one of the key stages of system development. To create a formalized and manageable decision-making structure, the problem must be represented in a form suitable for mathematical and computational analysis (Vaneeva *et al.* 2015). Depending on the modeling objective, tasks can be reduced to optimization problems (e.g., identifying the best route to avoid a threat), classification (determining the danger level of a situation), or forecasting (predicting the probability of system failure or emergency occurrence) (Table 2).

Table 2. Classification of aviation safety tasks by decision-making level.

Management level	Examples of tasks	Input data	Nature of threats
Strategic	Security system planning	Historical data, regulations	Long-term risks
Tactical	Personnel training, evacuation routes	Behavioral statistics, maps	Low probability scenarios
Operational	Real-time incident response	Sensor data, video streams	High criticality

Source: Elaborated by the authors based on FAA (2020).

The classification of aviation safety tasks highlights that decision-making requirements differ depending on both the time horizon and operational criticality. Strategic tasks focus on long-term planning and risk assessment, tactical tasks involve scenario preparation and personnel readiness, while operational tasks demand rapid, high-stakes responses. This differentiation underscores the necessity of developing specialized DSS approaches for each management level to ensure efficiency, reliability, and timely threat mitigation (FAA 2020).

A key approach in modeling decision-making is the use of methods from probability theory and game theory, which make it possible to account for uncertainty, alternative event development scenarios, and conflicts of interest. These methods are complemented by machine learning tools that enable models to adapt to new data, detect hidden dependencies, and improve prediction accuracy based on historical information (Kale *et al.* 2023).

Among specific models applied for formalizing decision-making, probabilistic graphs such as Bayesian networks are widely used, as they allow visualization of inter-variable relationships and assessment of event probabilities. Neural networks process large data arrays and identify complex, non-linear dependencies, while decision trees ensure result interpretability, which is essential when operators must quickly understand the rationale behind conclusions. The combined application of these models enables intelligent systems to analyze current situations and generate timely, justified recommendations, which are critical for preventing aviation incidents.

Decision support algorithms form the functional foundation of intelligent systems that ensure aviation safety. Their development relies heavily on both formalized methods and heuristics derived from accumulated expert knowledge. Such rules allow formalization of established solutions into algorithms applicable in standard situations, such as detecting technical malfunctions or passenger behavior deviations. However, as aviation processes become more complex, expert knowledge alone becomes insufficient, and more universal, adaptive algorithms are required (Lee *et al.* 2022).

Modern DSS processes massive data streams in real time – from onboard sensor signals and surveillance cameras to meteorological reports and ground service information. Filtering and intelligent analysis algorithms are applied to extract relevant information and promptly respond to threats, including data cleansing, anomaly detection, correlation analysis, and multidimensional data aggregation (Deng *et al.* 2021).

Multi-criteria analysis methods account for multiple risk factors and uncertainties when selecting response measures. These methods evaluate alternative actions according to criteria such as time, cost, reliability, and potential consequences, which is crucial under high complexity and limited decision-making time (Cankaya *et al.* 2023).

The most advanced DSS incorporate adaptive and self-learning algorithms capable of accumulating experience, adjusting behavior, and improving prediction accuracy over time. Systems based on machine learning and neural networks demonstrate high flexibility and adaptability to changing conditions, making them indispensable for maintaining stable, intelligent, and predictive aviation safety systems (Vojtek *et al.* 2021).

The architecture of DSS in aviation safety represents a multi-component structure that includes interconnected modules, each performing a crucial function to ensure timely and well-founded threat response (Table 3). At the core of DSS lies data collection and integration from diverse sources – primarily aircraft sensors, technical databases, airport and onboard surveillance systems, as well as meteorological services. These integrated data form the foundation for analyzing current states and identifying potential threats.

Table 3. Comparison of modeling methods for DSS tasks.

Method	Advantages	Disadvantages	Examples of application
Neural networks	High accuracy, learning capability	Difficulty of interpretation	Behavioral analysis
Decision trees	Simplicity of understanding, visualisation	Limited flexibility	Access control
Probabilistic graphical models (including Bayesian networks)	Operation with incomplete data, handling uncertainty	High computational complexity requires precise a priori knowledge	Threat scenario modeling, assessment of technical failures

Source: Elaborated by the authors based on The Boeing Company (2025). "Probabilistic graphical models" is a general category that includes Bayesian networks as a specific type used for assessing technical failures.

A key component of the system is the threat analysis and forecasting module. This component processes incoming information using signal processing algorithms, machine learning, statistical analysis, and probabilistic modeling. The module enables the system not only to detect current deviations but also to predict potential developments, ensuring the identification of risks at early stages. An integral part of the architecture is the operator interaction interface, which must be intuitive, informative, and adapted to high-workload conditions. The interface displays key information, issues risk warnings, proposes decision options, and allows the operator to respond rapidly. High ergonomics and visual clarity of the interface are critically important for minimizing perception time and preventing errors.

The final element of the architecture comprises feedback and adaptation mechanisms. The system must not only react to external events but also learn from its own experience – analyzing the effectiveness of previously made decisions, considering operator actions, and automatically adjusting internal models. Such adaptability allows DSS to remain relevant and reliable amid evolving threats and increasing complexity in the aviation environment.

The practical application of DSS in aviation safety covers a wide range of tasks aimed at reducing risks and improving situational control efficiency, both on the ground and in the air (Table 4).

The comparative analysis of decision support algorithms in Table 4 shows differences in accuracy, algorithm response time, and adaptability to new data. Hybrid neural networks demonstrate the highest accuracy (92%) and the fastest algorithm latency (80 ms), along with adaptive capabilities, making these systems effective for processing video streams and telemetry. Tree-based algorithms provide 85% accuracy and an average algorithm latency of 100 ms, with partial adaptability, suitable for handling

Table 4. Comparative analysis of DSS algorithms by key characteristics.

Algorithm	Accuracy (%)	Response time (ms)	Adaptation to new data	Data used
Heuristic search	75	120	No	Rules, scenarios
Neural network (hybrid)	92	80	Yes	Video stream, telemetry
KNN	78	200	Partial	Historical data, event logs
Tree-based algorithm	85	100	Partial	Sensor data, meteorological data
Multi-criteria analysis (analytic hierarchy process)	88	150	No	Expert assessments, weighting coefficients

Source: Elaborated by the authors based on EASA (2025). The "Response time (ms)" refers to algorithmic output latency, i.e., the time DSS algorithms require to generate results, not human operational response.

sensor and meteorological data. Multi-criteria analysis achieves 88% accuracy with an algorithm latency of 150 ms, though it lacks adaptability and relies on expert evaluations. K-nearest neighbors algorithms feature moderate accuracy (78%) and the longest algorithm latency (200 ms), with partial adaptability and use of historical data. Heuristic search has the lowest accuracy (75%) and a response time (algorithm latency) of 120 ms, with no adaptability, relying on predefined rules and scenarios. Such analysis allows for the selection of optimal algorithms depending on the requirements for accuracy, speed, and adaptability in specific aviation safety tasks.

An example of such systems is technology designed for detecting suspicious passenger behavior. These solutions integrate video surveillance, facial recognition algorithms, behavioral analysis, and micro-movement assessment. DSS are developed to analyze visual and behavioral parameters of passengers in real time. These solutions can match behavior against established profiles and notify operators when deviations are detected, potentially extending early response capabilities before boarding. Another application area involves monitoring equipment condition: telemetry data collected from onboard systems are processed using machine learning to identify possible signs of wear or instability in specific components. Such approaches enhance the predictability of technical failures and support more rational maintenance planning. Additionally, DSS are used in access control and facility monitoring systems. Airports employ digital platforms to track personnel and equipment movement, manage access to different zones, and record deviations from established norms. Integrating such solutions with external security databases can enhance situational awareness and simplify coordination during incident response.

Despite the rapid development of DSS in aviation safety, their implementation and improvement face several serious challenges. One of the main issues remains the integration of heterogeneous data from multiple sources – from onboard sensors and weather stations to surveillance cameras and airport management systems. These data differ in structure, format, timestamps, and reliability, requiring powerful processing and standardization tools to ensure coherent and synchronized system operation.

Ensuring the cybersecurity of DSS is among the primary challenges. As these systems process critical information and are connected to flight management infrastructure, they become potential targets for cyberattacks. Reliable data protection, encryption, user authentication, and network activity monitoring mechanisms are essential to prevent unauthorized access and manipulation.

The prospects for DSS development are directly linked to the integration of Big Data and IoT technologies. The massive interconnection of devices and detailed data collection at every stage of the aviation process opens new opportunities for deep analysis, forecasting, and automation. However, as the volume of information increases, so do the requirements for computational resources, system architecture, and processing algorithms.

Ensuring the cybersecurity of DSS is one of the tasks under consideration. Quantum algorithms are being explored as tools to accelerate complex computations, such as multi-criteria route optimization or emergency scenario modeling. Deep learning, in turn, expands the boundaries of automatic recognition of complex patterns within large data sets. These approaches create the foundation for developing intelligent and adaptive systems designed for threat response and prediction.

At the same time, it should be emphasized that the performance indicators presented in this study (including 92% accuracy and 80 ms algorithm latency for hybrid neural networks) were obtained through analytical modeling and evaluation based on historical datasets and statistical materials. Although these results demonstrate high potential efficiency, the models were not tested under real aviation operational conditions involving live data streams, high workload, and stress factors characteristic of active airports or air traffic control centers. Therefore, the reported performance metrics should be interpreted as validated within a controlled analytical framework rather than confirmed through full-scale operational deployment.

Future research should focus on pilot implementations of DSS in operational aviation environments, such as active airports, air traffic management units, or integrated monitoring centers. Empirical validation under real-time information overload, dynamic traffic conditions, and human-system interaction constraints would provide more robust evidence of system reliability, scalability, and resilience. Such field testing would allow assessment not only of algorithmic latency and prediction accuracy but also of practical usability, operator trust, and system behavior under stress conditions.

The analysis of the research results shows that integrating sensory data with adaptive mechanisms affects the efficiency of DSS in aviation. This indicates the need to consider both technical aspects and operator interface convenience to ensure fast and accurate information perception. Thus, a systemic approach to the structure of DSS contributes to the adaptation of decision-making processes under conditions of high dynamics and uncertainty.

DISCUSSION

During the study, modern approaches to the design of DSS models and algorithms in aviation safety tasks were analyzed. The data obtained confirmed the high importance of speed and accuracy in decision-making, which is especially critical in the event of emergencies or extreme situations. It was found that the automation of large-scale data analysis can significantly reduce the influence of the human factor, thereby minimizing risks associated with personnel errors.

This issue was also investigated by Mizrak and Akkartal (2024), whose results confirmed that DSS play a key role in aviation safety management, providing comprehensive data analysis and prompt risk assessment. The systems approach allows the integration of various sources of information – from technical parameters to the human factor – to form a holistic picture of ongoing events. As a result, the resilience of the aviation industry to potential threats increases through predictive analysis and proactive management.

The research of Ziakkas and Pechlivanis (2023) likewise showed that intelligent models based on machine learning and neural networks make it possible to instantly detect anomalies and trigger emergency protocols. This significantly reduces the response time of both the crew and dispatch services to critical situations. Consequently, the probability of preventing incidents and minimizing consequences in emergency conditions increases.

It should be noted that the efficiency of DSS directly depends on the quality of input data and the level of integration with other elements of the aviation infrastructure. Insufficient synchronization between systems may lead to delays in decision-making or misjudgment of the situation. Therefore, special attention should be paid to data standardization and the development of unified interaction protocols between subsystems.

A comprehensive data standardization procedure guarantees the uniformity of data formats, synchronization of timestamps, and normalization of reliability across diverse sources, including onboard sensors, surveillance systems, and meteorological platforms. This protocol increases data intake consistency and quality, minimizes processing delays, boosts the precision of threat detection algorithms, and facilitates the effective operation of prediction models under uncertainty. The protocol enhances timely and informed decision-making, consequently augmenting the resilience and robustness of aviation DSS.

Recent research in pertinent fields has shown the efficacy of sophisticated probabilistic learning models for managing heterogeneous data and predicting under uncertainty. Enhanced Bayesian dynamic linear models have been proposed for high-precision multi-step prediction and robust uncertainty quantification in structural health monitoring, effectively managing noisy and incomplete sensor data under extreme environmental conditions akin to operational aviation stressors.

Moreover, systematic reviews regarding the utilization of Bayesian networks in structural health monitoring underscore their significance in multi-source data fusion, uncertainty modeling, and decision support, thereby affirming their pertinence in intricate, heterogeneous aviation DSS scenarios where probabilistic reasoning and data integration are essential (Tashtay *et al.* 2026).

The study of aviation safety assurance tasks showed that the multi-level nature of processes requires flexible and adaptive systems capable of operating with incomplete and contradictory information. The analysis indicated that such systems must ensure rapid response and reliability, which requires the implementation of models based on probabilistic approaches and artificial intelligence. The research results also highlighted the necessity of using multi-aspect risk analysis for balanced decision-making.

Ramos *et al.* (2023) concluded that the design of aviation DSS must take into account constant changes in flight conditions, weather factors, and human interaction. Systems must be flexible, capable of quickly updating algorithms and retraining models in real time. It is also important to include forecasting modules that enable effective operation under incomplete or contradictory data (Sekenov *et al.* 2024).

In the study by Xiong *et al.* (2025), it was found that DSS algorithms should consider the complex hierarchy of aviation safety, from the tactical level (crew, maintenance) to the strategic level (national and international regulators). This necessitates the development of adaptive models capable of considering the decision-making context at each level. Only such an adaptation makes it possible to build a continuous risk management chain and ensure the coordination of actions among all participants.

These results confirm the findings presented above, demonstrating the effectiveness of a systemic approach in designing DSS within an unstable aviation environment. The findings show that integrating adaptive models and predictive mechanisms contributes to more accurate and timely operator support in decision-making. Thus, the implementation of such solutions not only enhances system resilience but also reduces the likelihood of critical errors under uncertainty.

The assessment of model performance must consider that it is predominantly reliant on historical data and modeling methodologies. Although such data offer a dependable foundation for trend analysis and algorithm validation, they fail to encompass the intricacies and fluctuations of real-time operating contexts. Consequently, additional research should concentrate on evaluating the suggested models in practical settings, encompassing pilot implementations within airport infrastructures and air traffic control systems. This validation would enable the evaluation of algorithm robustness in dynamic, high-load situations and the refinement of model parameters to guarantee practical flexibility and stability in operational contexts.

In the formalization of decision-making processes, various methods were explored – from classical optimization algorithms to modern machine learning and neural network models. The analysis showed that the application of probabilistic graphs and decision trees improves threat prediction quality and enhances DSS adaptability to changing operational conditions. The use of game theory made it possible to view interactions with potential threats as strategic tasks (Ketners 2025).

It is worth noting the work of Nogueira *et al.* (2023), who also found that probabilistic models make it possible to account for uncertainty in aviation processes and assess the likelihood of various incidents. Machine learning methods trained on historical data identify hidden dependencies and patterns that are difficult to detect through traditional means. Such forecasting significantly improves risk assessment accuracy and contributes to more effective flight safety management.

In turn, Tang *et al.* (2022) concluded that classification methods allow for the rapid determination of threat types and levels, providing a basis for the selection of optimal solutions. At the same time, game theory helps model interactions among different aviation system participants, including pilots, dispatchers, and technical personnel. Combining these approaches promotes more balanced and rational incident management under constrained resources and time.

These data align with the theses outlined in the previous section, confirming the importance of applying intelligent technologies to improve prediction accuracy and aviation system resilience. The analysis shows that the use of probabilistic and game models makes it possible to consider multiple scenarios and behavioral strategies of participants. This is particularly relevant in a rapidly changing environment, where traditional decision-making methods lose efficiency (Orazbayev *et al.* 2024).

Within the framework of DSS algorithm analysis, it was demonstrated that combining expert rules and heuristics with adaptive learning methods ensures high efficiency in real-time threat detection. The results showed that multi-criteria risk analysis helps account for multiple factors affecting safety and enables the selection of optimal response measures. Moreover, self-learning systems demonstrated potential for continuous improvement based on new data (Kondratenko *et al.* 2016b).

Verma and Singhal (2023) also conducted a study whose results confirmed that expert systems ensure the transfer of accumulated knowledge and experience, which is vital for supporting decision-making in complex aviation situations. Adaptive learning enables such systems to continuously improve, adjusting to new data and changing conditions (Beisenbi and Kaliyeva 2018; Bruno *et al.* 2019). The combination of these approaches enhances the accuracy and reliability of recommendations, reducing operator error risks.

Cui *et al.* (2022) likewise found that filtering algorithms help separate meaningful information from noise, which is critical when dealing with large data streams in the aviation environment. Multi-criteria analysis makes it possible to consider several factors simultaneously, such as safety, cost-efficiency, and timeliness. In real-time mode, this provides more balanced and justified decisions, contributing to effective risk and resource management.

By comparing the data obtained during the studies, it can be noted that the integration of expert systems with adaptive learning significantly improves the quality of decisions made in aviation. This approach enables not only the utilization of accumulated knowledge but also a rapid response to new challenges and changing conditions. This is especially important in critical situations, where the timeliness and accuracy of decisions directly affect flight safety (Babak *et al.* 2007; Tashtay *et al.* 2025).

The study of DSS architecture revealed that integrating heterogeneous data sources, including sensors, video surveillance systems, and meteorological information, is a key factor in forming a comprehensive threat picture. The analysis of forecasting and feedback modules confirmed the importance of creating user-friendly operator interfaces, which enhance human-system interaction efficiency. This enables timely adaptation of decisions to changing conditions and improves DSS reliability.

Nonetheless, assertions regarding the efficacy of intuitive interfaces in minimizing operator errors and decision-making durations are presently based on heuristic assumptions rather than empirical substantiation. Future research should integrate formal usability evaluation methodologies to address this gap. Eye-tracking studies can measure how operators visually engage with interface elements and reveal patterns that signify cognitive burden and attention allocation, as evidenced in aviation and simulator research (Smailov *et al.* 2025).

Cognitive load evaluations utilizing standardized tools like NASA-TLX or physiological indicators (e.g., eye gaze metrics associated with workload) can yield objective data regarding operator mental exertion and interface requirements during task performance.

Furthermore, simulator-based operator testing, which incorporates realistic scenarios characterized by stress and information overload, along with protocols such as "think-aloud" or retrospective think-aloud, can effectively measure decision time, error rates, and user satisfaction under controlled conditions, thereby empirically substantiating that the proposed interfaces indeed enhance performance.

Alharasees and Kale (2024) concluded that modern DSS in aviation are based on a multi-layered structure, starting with sensory data that provide the collection and primary processing of information about the state of the aircraft and its environment. The data then undergo filtering and analysis, after which the results are delivered to the operator through an intuitive interface to support decision-making. Adaptive mechanisms enable the system to respond flexibly to changing conditions, adjusting algorithms to the current situation and improving overall efficiency (Wójcik *et al.* 2022).

Ruh *et al.* (2023) found that ensuring DSS reliability and scalability requires a thorough analysis of relationships among architectural components, such as data processing, communication protocols, and decision-making modules. Such an integrated approach makes it possible to identify bottlenecks and optimize system element interaction. As a result, high performance and scalability are achieved, which is particularly important for DSS implementation across various aviation industry segments.

The analysis of the research results shows that integrating sensory data with adaptive mechanisms affects the efficiency of DSS in aviation. This indicates the need to consider both technical aspects and operator interface convenience to ensure fast and accurate information perception. Thus, a systemic approach to the structure of DSS contributes to the adaptation of decision-making processes under conditions of high dynamics and uncertainty.

The review of practical applications showed that models and algorithms are implemented in systems for detecting suspicious behavior, predicting technical failures, and automating access control. However, the study also revealed several challenges related to the integration of Big Data, cybersecurity assurance, and the need to introduce new technologies such as Big Data and IoT. This emphasizes the relevance of further research into quantum computing and deep learning to improve the efficiency of DSS.

CONCLUSION

As a result of the conducted research, both theoretical and applied foundations were developed for designing models and algorithms of DSS in aviation safety tasks. It was established that the use of intelligent systems significantly enhances response efficiency to critical situations through automated large-scale data analysis and reduction of human factor influence. The study paid particular attention to the formalization of tasks, considering the high level of uncertainty and risk inherent to the aviation industry.

Statistical data for 2024 show that the main causes of aviation incidents were crew errors (168 cases, 45%, average operational response time – 8 minutes), technical failures (92 cases, 24%, 12 minutes operational response time), weather conditions (48 cases, 13%, 5 minutes operational response time), security procedure violations (30 cases, 8%, 15 minutes operational response time), and other causes (35 cases). The potential preventability of such incidents using DSS reaches 75% in cases of procedural violations and 65% for crew errors.

The study demonstrated that applying machine learning, neural networks (accuracy 92%, algorithm response time 80 milliseconds), decision trees (85%, 100 milliseconds), and multi-criteria analysis (88%) improves threat prediction accuracy. Models applicable at strategic, tactical, and operational management levels were examined, including the processing of video streams, telemetry, meteorological data, and event logs.

Thus, the research goal was achieved: approaches to developing adaptive intelligent DSS capable of functioning under uncertainty and ensuring the reliable protection of aviation infrastructure were substantiated and designed.

A disadvantage of this study is that the presented performance indicators were obtained using historical data and analytical modeling, which may not entirely capture the complexity and variety of actual operational situations. Consequently, empirical validation via pilot implementations in functional airports and air traffic management systems is important. This real-world validation would enable the evaluation of algorithm robustness in dynamic, high-stress scenarios, refinement of model parameters, and assurance of practical adaptability and reliability in actual flight settings.

Further research should therefore prioritize empirical testing through pilot implementations within live aviation infrastructures. Such validation would enable assessment of system behavior under real-time stress conditions, information overload, dynamic air traffic flows, and direct human-system interaction. Additionally, future studies should examine large-scale integration of DSS with external monitoring platforms and international aviation incident databases to evaluate interoperability, scalability, and long-term operational sustainability.

CONFLICTS OF INTEREST

Nothing to declare.

AUTHOR CONTRIBUTION

Conceptualization: Dolzhenko N and Sagimov A; **Methodology:** Dolzhenko N, Sagimov A and Aitmukhanova G; **Software:** Akhmetov R and Bekmukhambetov A; **Validation:** Sagimov A, Aitmukhanova G, and Akhmetov R; **Formal analysis:** Aitmukhanova G and Akhmetov R; **Investigation:** Dolzhenko N, Sagimov A, and Bekmukhambetov A; **Resources:** Dolzhenko N and Bekmukhambetov A; **Data Curation:** Aitmukhanova G and Akhmetov R; **Writing - Original Draft:** Dolzhenko N and Sagimov A; **Writing - Review & Editing:** Aitmukhanova G, Akhmetov R, and Bekmukhambetov A; **Visualization:** Akhmetov R and Bekmukhambetov A; **Supervision:** Dolzhenko N; **Project administration:** Sagimov A; **Final approval:** Dolzhenko N.

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The data will be available upon request.

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DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE TOOLS

No artificial intelligence tools were used in the preparation, writing, analysis, or editing of this manuscript.

REFERENCES

[EASA] European Union Aviation Safety Agency (2025) European aviation environmental report 2025: executive summary and recommendations. [accessed July 1 2026]. https://www.easa.europa.eu/sites/default/files/eaer-downloads/EASA_EAER_2025_BROCHURE_WEB_%CE%95%CE%9D_v2.pdf

[FAA] Federal Aviation Administration (2020) FAA report on Aviation Safety Information Analysis and Sharing (ASIAS). [accessed July 1 2026]. https://www.faa.gov/sites/faa.gov/files/2021-11/FAA_Report_on_Aviation_Safety_Information_Analysis_and_Sharing_ASIAS_03312020.pdf

[ICAO] International Civil Aviation Organisation (2024) Safety report 2024. [accessed July 1 2026]. https://www.icao.int/sites/default/files/sp-files/safety/Documents/ICAO_SR_2024.pdf

Agrawal AV, Soni M, Keshta I, Savithri V, Abdinabievna PS, Singh S (2023) A probability-based fuzzy algorithm for multi-attribute decision-analysis with application to aviation disaster decision-making. Decis Anal J 8:100310. https://doi.org/10.1016/j.dajour.2023.100310

Ahmad A, Amjad R, Basharat A, Farhan AA, Abbas AE (2024) Fuzzy knowledge based intelligent decision support system for ground based air defence. J Ambient Intell Humaniz Comput 15(4):2317-2340. https://doi.org/10.1007/s12652-024-04757-3

Alharasees O, Kale U (2024) Aviation operators' total loads analysis by multi-criteria decision-making. J Air Transp Manag 118:102596. https://doi.org/10.1016/j.jairtraman.2024.102596

Babak V, Kharchenko V, Vasylyev V (2007) Using generalized stochastic method to evaluate probability of conflict in controlled air traffic. Aviat 11(2):31-36. https://doi.org/10.3846/16487788.2007.9635958

Beisenbi M, Kaliyeva S (2018) Synthesis of the control systems by the state of an object with single input and single output by a gradient-velocity method of A.M. Lyapunov vector functions. Int J Civ Eng Technol 9(10):2080-2086. https://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_9_ISSUE_10/IJCIET_09_10_205.pdf

Bruno MF, Molfetta MG, Pratola L, Mossa M, Nutricato R, Morea A, Nitti DO, Chiaradia MT (2019) A combined approach of field data and earth observation for coastal risk assessment. Sensors (Switzerland) 19(6):1399. https://doi.org/10.3390/s19061399

Cankaya B, Topuz K, Delen D, Glassman A (2023) Evidence-based managerial decision-making with machine learning: the case of Bayesian inference in aviation incidents. Omega 120:102906. https://doi.org/10.1016/j.omega.2023.102906

Cui X, Zhang X, Zhao Z (2022) Real-time safety decision-making method for multirotor flight strategies based on TOPSIS model. Appl Sci 12(13):6696. https://doi.org/10.3390/app12136696

Degas A, Islam MR, Hurter C, Barua S, Rahman H, Poudel M, Ruscio D, Ahmed MU, Begum S, Rahman MA, *et al.* (2022) A survey on artificial intelligence (AI) and explainable AI in air traffic management: current trends and development with future research trajectory. Appl Sci 12(3):1295. https://doi.org/10.3390/app12031295

Deng Q, Santos BF, Verhagen WJ (2021) A novel decision support system for optimizing aircraft maintenance check schedule and task allocation. Decis Support Syst 146:113545. https://doi.org/10.1016/j.dss.2021.113545

Eleimat M, Őszi A (2025) Cybersecurity in aviation: exploring the significance, applications, and challenges of cybersecurity in the aviation sector. Period Polytech Transp Eng 53(2):169-183.https://doi.org/10.3311/PPtr.37153

Garcia AB, Babiceanu RF, Seker R (2021) Artificial intelligence and machine learning approaches for aviation cybersecurity: an overview. Paper presented 2021 Integrated Communications Navigation and Surveillance Conference. IEEE; Dulles, USA. https://doi.org/10.1109/ICNS52807.2021.9441594

Insaurralde CC, Blasch E (2022) Situation awareness decision support system for air traffic management using ontological reasoning. J Aerosp Inf Syst 19(3). https://doi.org/10.2514/1.I010989

Insaurralde CC, Blasch EP, Costa PC, Sampigethaya K (2022) Uncertainty-driven ontology for decision support system in air transport. Electronics 11(3):362. https://doi.org/10.3390/electronics11030362

Kale U, Alharasees O, Rohacs J, Rohacs D (2023) Aviation operators (pilots, ATCOs) decision-making process. Aircr Eng Aerosp Technol 95(3):442-451. https://doi.org/10.1108/AEAT-02-2022-0053

Kerimkhulle S, Azieva G, Saliyeva A, Mukhanova A (2022) Estimation of the volume of production of turbine vapor of a fuel boiler with stochastic exogenous factors. E3S Web Conf 339:02006. https://doi.org/10.1051/e3sconf/202233902006

Ketners K (2025) Adaptation of state security to modern military operations and terrorist risks in the world. Space Cult India 13(1):1-5. https://doi.org/10.20896/e3p2jm77

Kondratenko Y, Gerasin O, Topalov A (2016a) A simulation model for robot's slip displacement sensors. Int J Comput 15(4):224-236. https://doi.org/10.47839/ijc.15.4.854

Kondratenko YP, Kozlov OV, Gerasin OS, Zaporozhets YM (2016b) Synthesis and research of neuro-fuzzy observer of clamping force for mobile robot automatic control system. Paper presented 2016 IEEE First International Conference on Data Stream Mining & Processing. IEEE; Lviv, Ukraine. https://doi.org/10.1109/DSMP.2016.7583514

Lazic DA, Grujic V (2022) Resolving crisis situations in aviation from the past as a prediction for their successful overcoming today. South Florida J Dev 3(3):4014-4028. https://doi.org/10.46932/sfjdv3n3-073

Lee CY, Puranik TG, Mavris DN (2022) Deep spatio-temporal neural networks for risk prediction and decision support in aviation operations. J Comput Inf Sci Eng 21(4):041013. https://doi.org/10.1115/1.4049992

Li J, Dai J, Issakhov A, Almojil SF, Souri A (2021) Towards decision support systems for energy management in the smart industry and Internet of Things. Comput Ind Eng 161:107671. https://doi.org/10.1016/j.cie.2021.107671

Martinez-Marquez D, Pingali S, Panuwatwanich K, Stewart RA, Mohamed S (2021) Application of eye tracking technology in aviation, maritime, and construction industries: a systematic review. Sensors 21(13):4289. https://doi.org/10.3390/s21134289

Maulana F, Starr A, Ompusunggu AP (2023) Explainable data-driven method combined with Bayesian filtering for remaining useful lifetime prediction of aircraft engines using NASA CMAPSS datasets. Machines 11(2):163. https://doi.org/10.3390/machines11020163

Mendes N, Vieira JGV, Mano AP (2022) Risk management in aviation maintenance: a systematic literature review. Saf Sci 153:105810. https://doi.org/10.1016/j.ssci.2022.105810

Milbredt O, Popa A, Doenitz FC, Hellmann M (2022) Aviation security automation: the current level of security automation and its impact. J Airpt Manag 16(2):184-208. https://doi.org/10.69554/ZFKK4145

Mizrak F, Akkartal GR (2024) Prioritizing cybersecurity initiatives in aviation: a DEMATEL-QSFS methodology. Heliyon 10(16):e35487. https://doi.org/10.1016/j.heliyon.2024.e35487

Nogueira RP, Melicio R, Valério D, Santos LFFM (2023) Learning methods and predictive modeling to identify failure by human factors in the aviation industry. Appl Sci 13(6):4069. https://doi.org/10.3390/app13064069

Orazbayev B, Tanirbergenova A, Orazbayeva K, Berikbaeva M, Kaliyeva S, Kurmangaziyeva L, Makhatova V (2024) Decision making for control of the gasoline fraction hydrotreating process in a fuzzy environment. Proces 12(4):669. https://doi.org/10.3390/pr12040669

Ramos MA, Sankaran K, Guarro S, Mosleh A, Ramezani R, Arjounilla A (2023) The need for and conceptual design of an AI model-based Integrated Flight Advisory System. Proc Inst Mech Eng O J Risk Reliab 237(2):485-507. https://doi.org/10.1177/1748006X221083379

Rathnakumar R, Liu Y (2025) Towards safer general aviation operations using a vision-based decision support system for weather threat avoidance. J Air Transp Manag 123:102709. https://doi.org/10.1016/j.jairtraman.2024.102709

Ruh ML, Sarojini D, Fletcher A, Asher I, Hwang JT (2023) Large-scale multidisciplinary design optimization of the NASA lift-plus-cruise concept using a novel aircraft design framework. arXiv. https://doi.org/10.48550/arXiv.2304.14889

Sekenov B, Smailov N, Tashtay Y, Amir A, Kuttybayeva A, Tolemanova A (2024) Fiber-optic temperature sensors for monitoring the influence of the space environment on nanosatellites: a review. Mech Mach Sci 167:371-380. https://doi.org/10.1007/978-3-031-67569-0_42

Singh S, Sharma SK, Parti R (2024) Role of aviation infrastructure in aviation operation. In: Khalid S, Siddiqui NN, editors. New innovations in AI, aviation, and air traffic technology. Hershey: IGI Global; p. 212-245. https://doi.org/10.4018/979-8-3693-1954-3.ch011

Smailov N, Nussupov Y, Taissariyeva K, Kuttybayev A, Baigulbayeva M, Turumbetov M, Hryhoriev Y, Lutsenko S (2025) Identification of dangerous situations in the road infrastructure using unmanned aerial vehicles. Technol Audit Prod Reserves 6(2):97-102. https://doi.org/10.15587/2706-5448.2025.347074

Tang X, Lu X, Zheng P (2022) Aircraft autonomous separation assurance based on cooperative game theory. Aerospace 9(8):421. https://doi.org/10.3390/aerospace9010042

Tashtay Y, Smailov N, Naubetov D, Sabibolda A, Nussupov Y, Kashkimbayeva N, Mailybayev Y, Batyrgaliyev A (2026) Fiber-optic gyroscopes: architectures, signal processing, error compensation, and emerging trends. J Sens Actuator Netw 15(1):3. https://doi.org/10.3390/jsan15010003

Tashtay Y, Smailov N, Tazhen K, Sabibolda A, Nazarova A, Bazarbay A (2025) Paper presented 2025 International Conference on Electrical Engineering and Photonics. IEEE; Saint Petersburg, Russian Federation. https://doi.org/10.1109/EExPolytech66949.2025.11253802

The Boeing Company (2025) 2025 Chief Aerospace Safety Officer Report. [accessed July 1 2026]. https://www.boeing.com/content/dam/boeing/boeingdotcom/safety/caso/caso-report-2025.pdf

Ukwandu E, Ben-Farah MA, Hindy H, Bures M, Atkinson R, Tachtatzis C, Andonovic I, Bellekens X (2022) Cyber-security challenges in aviation industry: a review of current and future trends. Information 13(3):146. https://doi.org/10.3390/info13030146

Vaneeva O, Kuriksha O, Sophocleous C (2015) Enhanced group classification of Gardner equations with time-dependent coefficients. Commun Nonlinear Sci Numer Simul 22(1-3):1243-1251. https://doi.org/10.1016/j.cnsns.2014.09.016

Verma A, Singhal N (2023) Integrating artificial intelligence for adaptive decision-making in complex systems. In: Das S, Saha S, Coello CAC, Bansal JC, editors. Selected papers from ADCIS 2023: advances in data-driven computing and intelligent systems. Singapore: Springer. p. 95-105. https://doi.org/10.1007/978-981-99-9521-9_8

Vojtek N, Petrović B, Milošević P (2021) Decision support system for predicting the number of no-show passengers in airline industry. Tech J 28(1):123-134. https://doi.org/10.17559/TV-20191215144655

Wang QA, Huang XY, Ni Y, Feng WS, Wang JF, Qiu S, Zhou P, Li JP, Luo Y (2026) Uncertainty-aware, high-precision multi-step prediction of structural health monitoring sensor streams under extreme typhoon events: an enhanced Bayesian dynamic linear model leveraging the kernel regression basis function for severe environmental adaptation. Measurement 262. https://doi.org/10.1016/j.measurement.2025.120050

Wójcik W, Kalizhanova A, Kulyk YA, Knysh BP, Kvyetnyy RN, Kulyk AI, Sichko TV, Dumenko VP, Bezstmertna OV, Adikhanova S, *et al* (2022) The method of time distribution for environment monitoring using unmanned aerial vehicles according to an inverse priority. J Ecol Eng 23(11):179-187. https://doi.org/10.12911/22998993/153458

Xiong M, Wang H, Hou Z, Wong YD (2025) Multi-level information identification for civil aviation safety risks: a hierarchical multi-branch deep learning approach. Inf Sci 702:1218888. https://doi.org/10.1016/j.ins.2025.121888

Ziakkas D, Pechlivanis K (2023) Artificial intelligence applications in aviation accident classification: a preliminary exploratory study. Decis Anal J 9:100358. https://doi.org/10.1016/j.dajour.2023.100358