

Pilots Perception of Flight Safety: An Analysis Based On A Flight Data Monitoring System

Muhittin APAYDIN¹, Vildan DURMAZ², Selim YILDIRIM³, Seçil ULUFER KANSOY⁴

¹Eskişehir Technical University, Institute of Social Sciences. (muhittin.apaydin@gmail.com). ORCID: 0009-0000-7106-5424

²Eskişehir Technical University, Faculty of Aeronautics and Astronautics. (vkorul@eskisehir.edu.tr). ORCID: 0000-0003-3649-1780

³Anadolu University, Faculty of Economics and Administrative Sciences. (syildirim@anadolu.edu.tr). ORCID: 0000-0002-7900-6813

⁴Kırklareli University, Faculty of Aeronautics and Astronautics (seciluluferkansoy@klu.edu.tr) ORCID: 0000-0002-5522-324X

Article Info

Received: 09.07.2026

Revised: 10.10.2026

Accepted: 11.10.2026

Published: 15.10.2026

Keywords:

Flight Safety, Flight Data Monitoring, Pilot Perception.

Jel Code:

Z00

Corresponding Author:

Muhittin APAYDIN

Research Article

<https://doi.org/10.5281/zenodo.23373682>

Abstract

Flight Data Monitoring (FDM) has become an essential component of modern Safety Management Systems by enabling the proactive identification of operational risks and supporting continuous safety improvement. While previous studies have primarily focused on the technical and analytical capabilities of FDM systems, limited attention has been given to pilots' perceptions of FDM and its contribution to operational decision-making. Therefore, this study aims to investigate pilots' perceptions of flight safety in relation to the use of FDM systems and to examine whether these perceptions differ according to demographic and professional characteristics. The study employed a quantitative research design. Data were collected through a structured questionnaire consisting of 24 items administered to 33 volunteer captain pilots and first officers employed by Air Albania. Statistical analyses were performed using SPSS 26. Independent samples t-tests and analysis of variance (ANOVA) were conducted to identify differences among demographic groups. The results revealed statistically significant differences in pilots' perceptions of FDM based on rank and age. Significant differences were identified between captains and first officers regarding their observations of safety and operational improvements resulting from FDM analyses. Furthermore, age-related differences were found in perceptions concerning the influence of FDM on operational decision-making processes. Unlike previous studies that predominantly focused on technical aspects of flight data analysis, this research examines the human and operational dimensions of FDM systems through pilots' perceptions. The findings contribute to the literature by demonstrating that the effectiveness of FDM systems depends not only on technological capabilities but also on pilots' acceptance, organizational support mechanisms, and safety culture.

Introduction

Flight safety is one of the most critical concerns in modern aviation, requiring pilots to accurately perceive, process, and respond to a wide range of information. Human factors, particularly pilot perception, significantly influence decision-making and operational performance during flight. To maintain their operations at a certain level, airlines must expand their scope and develop fuel-efficient solutions. Civil aviation has become a sector of interest within the transportation industry due to the use of advanced technology and a competitive environment. The concept of safety refers to the state of not encountering undesirable situations that could cause significant harm or lead to destruction or that have the potential to occur. In other words, it is defined as the state of being free from situations that could cause injury, damage, or death; it is also described as the absence of danger or immunity from injury, damage, or death (International Civil Aviation Organization ICAO Annex 19, 2011). However, it is difficult to say that situations posing no danger will never occur, especially during flight and when considering aircraft manufactured with advanced technology. Therefore, safety is a relative term that reflects the perceived and accepted level of risk, and it is a condition that exists and is possible in the aviation sector (Başak and Gülen, 2008). In its simplest sense, situational awareness is an individual's ability to understand what is happening in their surroundings. When considering the aviation industry, the environment is dynamic. In this environment, operations are constantly in flux, and at times, multiple tasks are performed simultaneously. It is of vital importance to maintain control over this entire process and take the necessary actions at the right time.

To fully develop situational awareness, one must master three fundamental stages. These stages (Endsley, 1999) are:

- The first stage is the perception of the environment,
- The second stage involves processing information into meaningful knowledge and synthesizing it,
- The third stage is making predictions about the future.

Safety can also be defined as the avoidance of loss of life, bodily injury, occupational disease, property damage, loss of facility usability and adverse environmental impacts (Aksoy, 2006). Various obligations, responsibilities to be fulfilled, authorities, and accountabilities should be established in safety management system procedures, and additional measures should be taken in this regard.

A safety management system consists of the scope of the safety management system, safety policy and objectives, safety obligations, the safety manager, documentation and control procedures, coordination of emergency action plans, hazard identification and risk management plans, safety assurance, safety performance monitoring, safety audits, change management, safety incentives, and contracted activities (ICAO Annex 19).

The concept of human factors is a discipline that examines the physical, cognitive, and social factors affecting human performance, safety, and efficiency in the civil aviation sector. Human factors contribute to areas such as aircraft design, training, operations, maintenance, ergonomics, communication, safety culture, human errors, and risk management skills. Human factors analysis examines the interaction between people and other system stakeholders, such as the environment, facilities, and equipment. It aims to ensure harmonious cooperation between people and the system (Bayat, 2008). The topic of human factors is considered mandatory training by ICAO. These training programs cover processes ranging from aircraft design to the manufacturing stage. Certification training encompasses all activities performed by cockpit and cabin crews, as well as the technical teams responsible for aircraft maintenance (Campbell & Jardine, 2001).

It is widely accepted worldwide that aircraft are the most reliable mode of transportation. However, although statistically rare, the accidents that do occur highlight the need to review safety measures and implement innovations. When examining the causes of accidents, the accident-fatality rate resulting from human errors—often considered minor—is quite high. Eliminating the causes of accidents—which are examined under headings such as flight crew, aircraft maintenance personnel, weather conditions during flight, and the geographical conditions of the airport or seaport—is the goal of all stakeholders involved in aviation (Yavuz, 2013).

These situations can stem from various factors, such as malfunctions in aircraft systems, weather conditions or human error. In aviation, abnormal situations that are unexpected may lead to undesirable events or conditions which pose potential threat to flight safety. Strategies for identifying and preventing abnormal conditions, used in the aviation industry to reduce accidents and incidents, manage risks, improve performance, and foster a culture of safety are as follows.

Safety Management System (SMS): This strategy involves a management approach used to systematically plan, implement, monitor, and improve safety in aviation operations. The SMS consists of four main components: safety policy, safety risk management, safety assurance, and safety promotion (Gemici, 2019).

Threat and Error Management (TEM): This strategy is a set of skills that pilots use to identify, prevent or manage threats (external factors) and errors (internal factors) they encounter during flight. TEM is used to enhance flight safety, reduce human-factor-related errors and improve crew resource management (Başdemir, 2020).

Flight Data Analysis (FDA): This strategy is a method used to analyses flight data recorded during a flight, evaluate flight performance, identify flight regimes, detect abnormal conditions, and take necessary measures. FDA is used to improve flight safety, quality, efficiency, and environmental impact. The FDA program ensures that flight analyses are regularly downloaded and recorded. As a result, a database related to this field is maintained, and information is shared. With advancing technology, many innovations have emerged, foremost among them being FDM (Flight Data Monitoring). Along with these technological advancements, FDM systems have evolved. The development of FDM systems will play a significant role in the future of the aviation industry. In the future, FDM systems will become even more complex and will be developed to further enhance flight safety, efficiency, and convenience (Wang B., Liu, Peng, & Peng, 2019). For example, the tremendous progress made in fields such as artificial intelligence (AI), Data analytics, the Internet of Things (IoT), and virtual reality (VR) has enabled FDM systems to become smarter, faster, more accurate, and more effective.

FDM is one of the proactive and predictive safety management tools included in the safety management system defined by ICAO. FDM directly contributes to risk management and safety assurance dimensions, which are fundamental components of the safety management system. By enabling the systematic identification of operational deviations and potential hazards through data collected during flights, the system

can develop regulatory and preventive measures before accidents and serious incidents occur. Furthermore, using the data obtained for the purpose of learning and improvement rather than punishment contributes to a culture of safety.

These technologies have improved the data collection, processing, analysis, interpretation, reporting, and feedback processes of FDM systems. They also play an effective role in the processes related to pilot training, performance evaluation, human factors analysis, resource analysis, and the efficient use of resources within FDM systems, as well as around error management within flight operations (European Aviation Safety Authority EASA, 2020).

The technologies used include:

Artificial Intelligence (AI): This technology is used to analyse flight data, evaluate flight performance parameters, determine flight regimes, detect abnormal conditions, and take the necessary measures. AI utilizes subfields such as machine learning, deep learning, natural language processing, computer vision, and speech recognition systems to understand, learn from, and predict flight data (Şen et al., 2020).

Modern aircraft collect data from numerous sensors during flight. This data is voluminous and complex. Artificial intelligence supports aviation safety efforts by analyzing this big data in areas such as data filtering and classification, and anomaly detection.

The machine learning algorithms learn normal operational values from historical flight data and use this information to detect future abnormalities. By proactively identifying potential hazards, swift action can be taken. For example, an algorithm that detects sudden increases in engine vibrations can ensure maintenance is performed before a failure occurs. AI-based systems can alert pilots in real time to dangerous situations. Additionally, these systems can simulate events to understand cause-and-effect relationships.

Internet of Things (IoT): This technology is used to collect, transmit, and store flight data, and consists of sensors, devices, networks, and cloud systems located on aircraft, at airports, at ground stations and in other relevant facilities.

Cloud computing: This technology is used to process, analyse, interpret, and report on flight data, as well as provide feedback. Cloud computing is a service that stores, processes, and delivers flight data on remote servers. This technology can enhance the security, accessibility, scalability, and cost-effectiveness of flight data (Keleş and Keleş, 2018). Cloud computing plays a crucial role in the aviation sector by significantly contributing to the digitization of operational processes, enabling more secure data management, and ensuring a seamless flow of information among various stakeholders without disruptions (Tutkun and Bilal, 2025).

IoT devices ensure that the numerous sensors and systems on board an aircraft remain in constant communication. Thanks to real-time data stream, pilot control inputs, weather conditions, and aircraft system information can be obtained instantly, and since all systems on board are interconnected, data monitoring systems can gather more comprehensive information.

Pilots' Concerns and Solutions Regarding FDM

When viewed from the outside, decision-making appears to be a very simple action. However, the act of decision-making is the result of a process. During this process, the pilot generates a wide range of options. They evaluate all options and select the most appropriate course of action. Since the resulting decision is made under time pressure, this increases the likelihood of making a wrong decision. Pilots generally implement the first viable decision rather than comparing many options to make the best one (Simpson, 2001).

The concerns and solutions of pilots and airlines are an important issue in the aviation industry. Pilots and their respective airlines may encounter various issues that can affect flight safety and security, the smooth operation of flights, company efficiency, and all performance metrics. These issues include the following:

Pilots' health: It is crucial for flight safety that pilots are in good health. Pilots receive their flight fitness certificates after undergoing health checks before, during, and after flights. However, pilots' health status can change over time, and factors such as stress, fatigue, sleep disorders, depression, and alcohol or substance abuse encountered during flight can negatively affect pilots' performance and flight safety. For this reason, pilots' health-related conditions must be continuously monitored and addressed (Oğuz, 2015).

Pilot education and development: Pilot training and development are crucial for flight quality and efficiency. Pilots receive theoretical and practical training at flight schools or airlines. However, pilot training and development are not limited to flight skills alone. Pilots must also possess non-technical competencies

such as human factors, crew resource management, threat and error management, communication, leadership, decision-making, problem-solving, and stress management. Training programs for pilots should incorporate and implement the latest methods, technologies, and standards to enhance their education and development (Hartzler, 2013).

Airline costs and competition: Airlines implement various strategies to manage costs and competition. They strive to control their fixed and variable costs, such as fuel, personnel, maintenance, insurance, taxes, and airport fees. In addition, airlines compete with their rivals to maintain or increase their market share. For this reason, airlines use cost reduction to increase revenue, enhance customer satisfaction, and improve operational efficiency and quality (Davis et al., 2008).

Automated Reporting Processes

Automated reporting systems and notification mechanisms are technological tools used to collect and process data, analyses and interpret the resulting data, and following all these processes, generate reports and present them to the relevant individuals or organizations. Automated reporting systems and notification mechanisms are used across various industries and fields for purposes such as data-driven decision-making, performance measurement, quality improvement, risk management, auditing, compliance, training, and feedback. Automated reporting systems and notification mechanisms encompass data sources, report design, report format, report distribution, report security, report monitoring, and report updates.

In automated reporting processes, data is collected via the FDR (Flight Data Recorder) and QAR (Quick Access Recorder). The collected raw data is checked for accuracy. Incorrect, incomplete, or corrupted data is detected and filtered out by the system. The data obtained here is compared against defined flight limits and safety parameters. The reporting process is carried out according to predefined templates. Report types may include a daily operations report (a summary for each flight), a systematic limit violation report (analysis of recurring errors), and a safety performance report (long-term trends and risk analysis).

FDM Applications for Airlines

The European Union (EU) Flight Data Monitoring (FDM) regulation is defined under Commission Regulation (EU) No 965/2012 (specifically Annex III, Part-ORO, rule ORO.AOC.130), requiring commercial air transport aeroplane operators with a maximum certificated take-off mass over 27,000 kg to run a proactive, non-punitive digital flight data analysis program (Commission Regulation (EU) No 965/2012)

Safety is the state in which risks associated with aviation activities, related to or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level. (ICAO 2022)

The development of FDM systems will play a significant role in the future of the aviation industry. In the future, FDM systems will become even more complex and will be developed to further enhance flight safety, efficiency, and convenience (Wang et al., 2019). Aircraft must obtain a flight permit to conduct aviation operations, and this permit can be obtained with an Airworthiness Inspection Certificate confirming that the aircraft has undergone regular maintenance.

The purpose of this study is to identify the perceptions of pilots working in the aviation industry worldwide regarding the FDM system, to examine the effects of flight safety improvement initiatives on airline safety, and to use the findings as a reference for both the aviation industry and future research.

A review of the literature reveals that research on FDM systems is quite limited. This gap highlights the importance of the present study and its potential to fill a gap in literature. A literature review on this topic has been conducted, and the studies examined are summarized in the table below.

Although previous studies have demonstrated the effectiveness of Flight Data Monitoring (FDM) systems in anomaly detection, operational performance monitoring, machine learning applications, and proactive safety management, limited attention has been paid to pilots' perceptions of FDM systems. The studies conducted by Li (2009; 2015; 2016), Chrysanthos (2014), Walker (2017), Oehling and Barry (2019), and Zhao et al. (2021) primarily focused on the technical capabilities of FDM systems and their contribution to operational safety. In contrast, the present study examines the human dimension of FDM by exploring pilots' perceptions regarding the effectiveness, usefulness, and operational impact of these systems. Therefore, this research extends the existing literature by addressing a relatively underexplored area, namely the interaction between pilots and FDM systems, and the extent to which pilots perceive FDM as a tool supporting flight safety and operational decision-making

Study Name	Author	Date	Purpose	Conclusion	Reference
Anomaly Detection in Airline Routine Operations Using Flight Data Recorder Data	Li	2009	The aim of this study is to develop a new anomaly detection approach that will support proactive safety management by utilizing routine flight data recorder (FDR) data. To this end, the study aims to use clustering analysis to identify risks before accidents occur, detect performance deviations early, and identify new types of anomalies that existing methods cannot detect.	The results of the study demonstrated that the cluster-based anomaly detection approaches developed (ClusterAD-Data Sample and Clustered-Flight) can detect operationally significant and novel anomalies, surpassing the capabilities of existing methods. It was determined that different algorithms specialize in detecting different types of deviations (pattern-based, instantaneous, or discrete parameter sequences); therefore, it was concluded that a “hybrid” approach combining these methods would offer superior performance. Furthermore, it was observed that visualization tools significantly reduced the time required for expert review; in summary, it was concluded that this new system offers a promising tool for airlines in the areas of early detection of hidden safety risks, predictive maintenance, and improving education.	Li, 2009
Kernel Methods for Flight Data Monitoring.	Chrysanthos	2014	To investigate machine learning methods for detecting “atypical flights”—which cannot be identified using traditional methods and may lead to operational safety issues—and to develop new “kernel methods” for this purpose. Accordingly, the goal is to create an unsupervised and robust anomaly detection model (using dimension reduction and dynamic time warping techniques) that is suited to the nature of the Flight Data Monitoring (FDM) system.	The results of the study show that, using a new unsupervised anomaly detection method developed based on information theory (Rényi entropy), outliers in clusters containing a high proportion of anomalous data were successfully detected. In addition, a new kernel was constructed that is mathematically well-defined and capable of performing computations faster than existing methods for analyzing flight data. Testing these developed techniques on real airline datasets (Airline1 and Airline2) demonstrated that the approach complements classical event-based detection systems and produces highly beneficial results.	Chrysanthos, 2014
An Analysis of the Effects of Air Traffic Management on Aircraft Fuel Consumption and Emissions Based on Actual Flight Data, and a Proposed Model	Canarslanlar	2015	In this study, the relationship between both fuel consumption and emission levels on domestic flights and ATM was demonstrated based on actual data. To this end, fuel consumption and the resulting emission levels were determined for the airport vicinity, the Terminal Maneuvering Area (TMA), and the taxi phase. To determine ATM flight inefficiencies at and around airports, the phase durations of the Landing and Take-off Cycle (LTO) were determined for each airport included in the study and compared with the ICAO LTO. To determine ATM flight inefficiencies in the TMA and en-route phases, horizontal and vertical flight inefficiency analyses were conducted for domestic flights. As a result of these analyses, an ATM flight inefficiency model was developed to enable the easy measurement of ATM inefficiencies without the need for complex calculation methods.	The study found that the operational LTO cycle, calculated using actual flight data, showed significant differences from the ICAO standard cycle; compared to the standards, taxi-out (59%), climb (45%), takeoff (29%), and taxi-in (26%) times were shorter compared to the standards, while the approach phase took 15% longer due to vertical separations. It was observed that the route with the highest horizontal inefficiency—IST-DNZ (44.9%)—was the one most in need of improvement, and that significant differences in efficiency (e.g., ESB-IST 28.3%, IST-ESB 15.2%) arose in reciprocal flights between airport pairs due to procedural differences. Furthermore, it was concluded that vertical inefficiencies stem primarily from approach plans and procedures during the descent phase, as opposed to the climb phase.	Canarslanlar, 2015

Alircraft Performance Monitoring from Flight Data	Krajček, Nikolić, & Domitrović	2015	The purpose of this study is to provide an overview of existing performance monitoring methods and to offer initial insights into new research opportunities for determining the physical characteristics of operational aircraft using flight data, in order to track “actual aircraft performance” that deviates from the theoretical values in the flight manual due to factors such as structural aging and high dynamic loads.	The research found that existing methods, which rely solely on fuel consumption measurements derived from steady-state flight data, are insufficient for determining other important performance parameters, such as the aircraft’s maximum climb rate or service ceiling. Instead, it has been demonstrated that aerodynamic coefficients can be estimated using “system identification methods” based on data recorded by the QAR (Quick Access Recorder) unit during flight. It has been concluded that this newly developed aerodynamic monitoring system can provide a much more accurate and comprehensive calculation of “actual aircraft performance” by offering additional information on the types of physical disturbances on the aircraft fuselage.	Krajček, Nikolić, & Domitrović, 2015
Analysis of Flight Data Using Clustering Techniques for Detecting Abnormal Operations	Li, Das, Hansman, Palacios, & Srivastava	2015	The purpose of this study is to address the shortcomings of current methods in the airline industry that limit proactive risk management efforts and fail to identify new issues because they rely solely on predetermined criteria. Accordingly, by applying clustering techniques to data obtained from flight data recorders, this study aims to introduce a new method called “cluster-based anomaly detection” that can identify abnormal flights (unique data patterns) without requiring predefined criteria or domain knowledge, thereby supporting domain experts.	The results of the study demonstrated that the “Cluster AD-Flight” method, developed to analyze routine flight data, can successfully detect abnormal flights and hidden risks without requiring prior knowledge of anomalies. Comparisons revealed that Cluster AD-Flight is more sensitive in detecting abnormal patterns in continuous parameters and known safety issues, while the MKAD method performs better in identifying unusual sequences in discrete parameters. Considering these findings, it was concluded that a “hybrid” approach combining the strengths of both methods should be adopted in the future; furthermore, reinforced learning models supported by expert reviews should be developed to reduce false alarms, and the system should be extended to cover all phases of flight.	Li, Das, Hansman, Palacios, & Srivastava, 2015
An Incremental Clustering Method for Anomaly Detection in Flight Data	Li, Hansman, Palacios & Welsch	2016	This article presents a new approach to applying data mining in flight data analysis that enables aviation safety experts to identify hidden risks in daily operations without specifying in advance what to look for.	It has been observed that the ‘ClusterAD-DataSample’ method, tested on real-world datasets, can detect operationally significant anomalies without requiring extensive initial setup and successfully represents increasing risk levels. When compared to other data-driven methods, it has demonstrated superior performance in detecting known security incidents. However, it has been noted that further research is needed to comprehensively evaluate the method’s performance in detecting unknown issues.	Li, Hansman, Palacios, & Welsch, 2016
Monitoring Safety During Airline Operations: A System Approach.	Scarinci	2017	This study presents a new approach to monitoring and analyzing flight data to help airlines identify unsafe system behavior during operations.	The research found that traditional event-based overrun analysis is insufficient for processing the ever-growing volume of FOQA (Flight Operations Quality Assurance) data; therefore, the STAMP and STPA approaches—which are accident causality models—were used to improve this analysis. The study took a holistic approach to hardware, software, and human-automation interaction (pilot practices); by combining STPA concepts with “hypothesis-driven engineering,” it established a systematic method that enables the identification of new “leading indicators” (events) with	Scarinci, 2017

				proactive characteristics for FOQA data analysis.	
Redefining the incidents to learn from: Safety science insights acquired on the journey from black boxes to Flight Data Monitoring	Walker	2017	This article briefly examines the history of black boxes and relates it to the fundamental knowledge base of safety science. It then discusses Flight Data Monitoring (FDM) as an example of the paradigm shift from lagging indicators to leading indicators, which is necessary to continue learning from incidents.	The study revealed that the vast amounts of routine operational data collected in aviation are not yet being utilized to their full potential; however, integrating this Big Data with Flight Data Monitoring (FDM) processes offers significant opportunities, particularly in understanding “human factors.” It was emphasized that in safety science, a shift from “lagging indicators” (learning from disasters) to “leading indicators” (a proactive model) that detect weak signals in routine operations is essential. Furthermore, it was concluded that the data monitoring architecture successfully implemented in the aviation sector could be adapted to other industries with modern data collection infrastructure.	Walker, 2017
Using machine learning methods in airline flight data monitoring to generate new operational safety knowledge from existing data.	Oehling and Barry	2019	The purpose of this study is to investigate the potential of using machine learning (ML) methods to generate new safety-related insights from existing flight data. Airlines routinely generate large amounts of flight data through routine monitoring, but the concept of deriving safety insights from this data still relies on detecting when expert-defined thresholds are exceeded. This system cannot conceptually recognize new patterns that do not fit these filters. Machine learning techniques can address this gap.	The results of the study demonstrated that the application of the LoOP algorithm can enhance existing FDM (Flight Data Monitoring) analyses and detect approach anomalies even in the absence of a specific incident. It has been demonstrated that the developed method can be used not only to detect safety anomalies but also to identify anomalies related to the economic operation of aircraft and to analyze large flight data sets by higher-level authorities such as national aviation authorities. This study, which successfully identifies safety-related events that typical FDM systems cannot detect, suggests that future research should include comparisons with the performance of other outlier detection methods.	Oehling & Barry, 2019
An Incremental Clustering Method for Anomaly Detection in Flight Data	Zhao, Li, Alam, & Wang	2021	The aim of this study is to overcome the time and memory constraints arising from the need to cluster the data from scratch each time when using existing offline anomaly detection methods for the analysis of ever-growing flight data (FDR/QAR). To solve this problem, we aim to develop and propose a new Gaussian Mixture Model (GMM)-based anomaly detection method that can incrementally update clusters based on newly arriving data, rather than processing the entire dataset from the beginning.	The results of the study demonstrated that the new “incremental clustering method” proposed for detecting anomalies in flight data can identify new clusters in dynamically growing datasets, update existing ones, and merge redundant clusters. Tests conducted on both labeled simulation data and unlabeled real-world data have proven that this new method can produce results comparable to those of the traditional “one-time GMM clustering” method. Furthermore, it was noted that additional validation and the development of new tools will be required in the future for the method to be used in airline safety management and pilot training.	Zhao, Li , Alam, & Wang, 2021
Analysis of Data from Flight Data Recorders (FDRs) and Similar Devices Used to Determine the Causes of Aircraft Accidents and Incidents Through Case Studies, and the Development of a New Method for This Purpose	İnan	2021	The aim is to demonstrate the role of a new method—which enables the transmission of data from an aircraft in flight to a ground station via an RF (radio frequency) data linking identifying the causes of aircraft accidents and incidents. The study also aims to present a statistical summary of commercial flight accidents between 1959 and 2016, examine human factors theory, analyze the critical impact of FDR/CVR devices on civil aviation accidents through case studies, and investigate FDA	The results of the study revealed the critical importance of “human factors” and CRM (Crew Resource Management) training in aviation accidents, as demonstrated by the two comparative accident analyses examined. While FDR and CVR data definitively established that inadequate crew coordination caused the civilian jet accident, the root cause of the military training aircraft (T-37C) accident—in which no FDR or CVR devices remained speculative despite four separate investigations. In this context, it has been concluded that equipping all training aircraft—including military training aircraft—	İnan, 2021

		(Flight Data Analysis) processes in routine flights.	with FDR and CVR devices is mandatory to clearly determine the causes of accidents.
Pilot Flying Versus Pilot Monitoring: The Effect of Role Assignment on Pilots' Perceived Risk in Flight Simulation Experiment	Gao, S., Wang, L., Zhang, N., Bai, Y., Tian, 2025 Y., Chen, S., . . . Zhou, H	The purpose of this study is to examine how two different roles in the cockpit (the pilot flying—PF—and the pilot monitoring—PM) shape pilots' perception of risk in the aviation field. Accordingly, perceived risks were measured through psychophysiological responses in simulation experiments designed with professional pilots, with the goal of comparing the differences between the two distinct cockpit roles.	The study found that when pilots were in the pilot flying (PF) role, they exhibited greater physiological arousal and reported a higher perceived level of risk compared to when they were in the pilot monitoring (PM) role. This finding, which reveals an “asymmetric risk perception process” between cockpit roles, indicates that traditional aviation risk perception models must also incorporate the effects of controllability and responsibility. From a practical perspective, it was concluded that scenario-based specialized training—including strategies such as role-swapping—is needed to mitigate the negative effects of differing risk perceptions among crew members, enhance cooperation, and improve flight safety.

Method

This study employed a quantitative, cross-sectional research design to examine pilots’ perceptions of Flight Data Monitoring (FDM) within the contexts of flight safety, operational decision-making, organizational practices, and pilot performance. The study further investigated whether perceptions of FDM varied according to selected demographic and professional characteristics of the participants. The questionnaire included variables with different levels of measurement and addressed distinct aspects of FDM. Each variable was therefore evaluated according to its measurement characteristics and substantive meaning. Numerical values assigned to categorical responses were used for data coding and did not imply equal quantitative distances between response categories. In particular ordinal categories represent an inherent ordering of responses, while the intervals between consecutive categories cannot necessarily be considered equivalent (Sullivan & Artino, 2013).

The accessible population consisted of pilots employed by Air Albania during the data collection period. No sampling procedure was applied, as the study sought to reach the entire pilot population within the airline. All 33 pilots, comprising captains and first officers, voluntarily participated in the research. The resulting dataset therefore covered the accessible pilot population of the airline during the study period. As the research was conducted within a single airline, the findings were interpreted within the organizational and operational context of Air Albania. Generalization of the results to broader pilot populations was approached with caution.

Data were collected through a structured questionnaire designed to examine pilots’ experiences with and perceptions of FDM. The research instrument comprised 23 variables. Three variables addressed participants’ demographic and professional characteristics, while the remaining 20 questions focused on different aspects of FDM.

The questionnaire addressed FDM training and interaction with the system, its perceived contribution to flight safety, identification of potential safety hazards, perceived effectiveness, operational improvements associated with FDM analysis, organizational support, implementation challenges, safety culture, strengths and weaknesses of existing FDM practices, usability, privacy and confidentiality, data access and security, organizational policies and procedures, operational decision-making, changes in flight practices, pilot performance, and the use of FDM data in pilot training.

The questions employed different response formats in accordance with the characteristics of the information being collected. The questionnaire therefore contained dichotomous and multicategorical nominal variables as well as ordinal variables representing ordered levels of perception or evaluation. Numerical codes assigned to nominal categories were treated exclusively as coding conventions and were not interpreted as indicators of magnitude.

Combining multiple items into a composite scale requires evidence that the items represent a common underlying construct and that the resulting measurement structure demonstrates adequate dimensionality,

validity, and reliability (Boateng et al., 2018). The questions used in the present study addressed distinct operational, organizational, and individual aspects of FDM. Consequently, the substantive questionnaire items were analyzed as separate variables according to their respective measurement characteristics, and an overall FDM perception score was not calculated.

Participation in the research was voluntary. Participants were informed about the purpose and scope of the study before completing the questionnaire. The questionnaire was subsequently administered to pilots employed by Air Albania. Responses were numerically coded to facilitate statistical analysis. The measurement characteristics of each variable were preserved during the coding process. Numerical codes assigned to nominal responses were treated as category identifiers, whereas the inherent ordering of response options was retained for ordinal variables. Following data collection, the dataset containing responses from 33 participants was screened for valid cases, coding consistency, and conformity with the predefined response categories. Data were analyzed using IBM SPSS Statistics version 26. The analytical procedures were selected according to the level of measurement and distributional characteristics of the variables. Descriptive statistics were initially used to summarize participant characteristics and response distributions. Nominal and ordinal variables were reported using frequencies (*n*) and percentages (%). The inherent ordering of ordinal response categories was retained throughout the analyses. Numerical category codes were not treated as continuous measurements because numerical coding does not establish equal intervals between adjacent response categories (Sullivan & Artino, 2013).

Inferential analyses were conducted to examine relationships between FDM-related responses and relevant demographic and professional characteristics. Associations between categorical variables were evaluated using Pearson's chi-square test when the assumptions concerning expected cell frequencies were satisfied. Fisher's exact test was used when small, expected cell frequencies limited the appropriateness of the chi-square approximation. Fisher's exact test provides an appropriate method for examining associations between categorical variables in small samples and sparse contingency tables (Warner, 2013). For ordinal outcomes involving two independent groups, the Mann-Whitney U test was applied when the structure and distribution of the data supported a meaningful comparison. Comparisons involving more than two independent groups were conducted using the Kruskal-Wallis test where appropriate. These rank-based procedures were selected in accordance with the ordinal nature of the relevant variables and the absence of an assumption of equal intervals between adjacent response categories (Sullivan & Artino, 2013).

Inferential testing was restricted to comparisons that were conceptually relevant to the research objectives and statistically interpretable within the available data. Variables characterized by highly concentrated response distributions or insufficient observations across comparison groups were evaluated descriptively when inferential testing could not provide a stable or meaningful estimate. This analytical strategy was adopted to reduce the risk of overinterpreting unstable statistical results within the study population of 33 pilots.

All statistical tests were two-tailed, and the level of statistical significance was set at $p < .05$. Exact p values were reported where applicable. Inferential findings were interpreted cautiously in consideration of the number of participants and the single-airline research setting. Ethical approval for the study was granted by the Ethics Committee of the Rectorate of Eskişehir Technical University under Decision No. E-87914409-050.04-94948, dated August 14, 2025. Participation was voluntary, and the collected data were used for scientific research purposes. The findings were reported in a manner that did not permit the identification of individual participants.

Findings

The findings are presented in accordance with the measurement characteristics of the variables and the analytical framework defined in the study. The analysis first describes the demographic and professional characteristics of the participants, followed by the distribution of responses concerning the safety, operational, organizational, and performance-related aspects of FDM. Subsequently, selected FDM-related perceptions are examined across demographic and professional groups using appropriate non-parametric statistical procedures.

Table 1. Demographic and Professional Characteristics of the Participants

Variable	Category	n	%
Age	21–30 years	10	30.3
	31–40 years	6	18.2
	41–50 years	9	27.3
	50 years and above	8	24.2
	Total	33	100.0
Flight experience	1–5 years	13	39.4
	6–10 years	5	15.2
	10 years and above	15	45.5
	Total	33	100.0
Current rank	Commander	17	51.5
	Co-pilot	16	48.5
	Total	33	100.0

Table 1 presents the demographic and professional characteristics of the participants. The largest age group consisted of pilots aged 21–30 years (30.3%), followed by those aged 41–50 years (27.3%) and those aged 50 years or above (24.2%). Pilots aged 31–40 years represented 18.2% of the participants. In terms of flight experience, 45.5% had 10 years or more of professional experience, while 39.4% had between 1 and 5 years of experience. The remaining 15.2% reported 6–10 years of flight experience. The distribution by current rank was nearly balanced, with commanders accounting for 51.5% of the participants and co-pilots for 48.5%.

Table 2. Descriptive Findings on Pilots' Perceptions and Experiences Regarding FDM

Variable	Response	n	%
FDM Training	Yes	13	39.4
	No	20	60.6
	Total	33	100.0
Interaction with FDM Data	Often	3	9.1
	Rarely	19	57.6
	Upon request by the Safety Department	11	33.3
	Total	33	100.0
Perceived Benefits of FDM	Identifying weaknesses	4	12.1
	Identifying the overall safety level	14	42.4
	Improving overall safety	2	6.1
	Identifying overall trends	11	33.3
	Monitoring all flights	2	6.1
	Total	33	100.0
Proactive Identification of Safety Issues	Yes	13	39.4
	No	12	36.4
	Maybe	8	24.2
	Total	33	100.0
Effectiveness in Performance and Decision-Making	Very effective	13	39.4
	Effective	12	36.4
	Somewhat effective	8	24.2
	Total	33	100.0

Table 2 presents descriptive findings concerning the participants' previous FDM training, interaction with FDM data, and perceptions of its contribution to flight safety and pilot performance. Of the 33 participants, 39.4% reported having received training on the functioning of FDM and its importance for aviation safety, whereas 60.6% had received no such training. Interaction with FDM data during daily operations was generally limited: 57.6% of the participants reported interacting with FDM data rarely, 33.3% did so upon request by the Safety Department, and 9.1% reported frequent interaction. Regarding the perceived benefits of FDM for flight safety, identifying the overall safety level was the most frequently reported benefit (42.4%), followed by identifying overall trends (33.3%). Responses were more heterogeneous when participants were asked whether FDM could identify potential safety issues before they developed into accidents or incidents. While 39.4% agreed with this statement, 36.4% disagreed and 24.2% selected the uncertain response.

Table 3. Descriptive Findings on FDM-Related Safety and Organizational Perceptions

Variable	Response	n	%
Observed Safety or Operational Improvements	Yes	31	93.9
	No	1	3.0
	Maybe	1	3.0
	Total	33	100.0
Effectiveness in Identifying Safety Hazards	Very effective	11	33.3
	Effective	17	51.5
	Somewhat effective	5	15.2
	Total	33	100.0
Organizational Support for FDM	Yes	19	57.6
	No	3	9.1
	Maybe	11	33.3
	Total	33	100.0
Perceived Barriers to FDM Implementation	Yes	9	27.3
	No	10	30.3
	Maybe	14	42.4
	Total	33	100.0
Impact on Organizational Safety Culture	Improved safety awareness	4	12.1
	Reduced safety risks	12	36.4
	Increased reporting of safety concerns	8	24.2
	Encouraged a proactive safety approach	9	27.3
	Total	33	100.0

As presented in Table 3 participants reported predominantly favorable perceptions of the safety-related functions of FDM. A substantial majority of the pilots (93.9%) indicated that they had observed an instance in which FDM data analysis contributed to a safety or operational improvement. Only 3.0% reported that they had not observed such an improvement, while a further 3.0% selected the uncertain response. Participants also evaluated FDM positively in terms of identifying and addressing safety hazards. More than half (51.5%) considered FDM effective for this purpose, 33.3% rated it as very effective, and 15.2% described it as somewhat effective.

Evaluations of organizational support for FDM were more varied. While 57.6% of the participants considered the organizational support provided for FDM to be adequate, 33.3% were uncertain and 9.1% considered it inadequate. Responses concerning potential barriers to effective FDM implementation also showed a less concentrated distribution. Specifically, 27.3% of the participants reported the presence of such barriers, 30.3% reported no barriers, and 42.4% were uncertain.

Table 4. Descriptive Findings on FDM System Characteristics, Usability, and Data Confidentiality

Variable	Response	n	%
Strengths of FDM Systems	Identification of individual pilot errors	9	27.3
	Identification of systematic pilot errors	3	9.1
	Identification of operational errors	6	18.2
	Identification of overall trends	14	42.4
	Identification of individual aircraft-related issues	1	3.0
	Total	33	100.0
Weaknesses of FDM Systems	Data security concerns	1	3.0
	Risk of data misuse	16	48.5
	Inadequate analysis of collected data	13	39.4
	Limited organizational feedback	3	9.1
	Total	33	100.0
User-Friendliness of FDM Systems	User-friendly	5	15.2
	Moderately user-friendly	18	54.5
	Slightly user-friendly	2	6.1
	Not user-friendly	8	24.2
	Total	33	100.0
Privacy and Confidentiality Concerns	Yes	2	6.1
	No	16	48.5
	Maybe	15	45.5
	Total	33	100.0
Secure Management and Access to FDM Data	Access restricted to the Safety Department and use in accordance with safety procedures	19	57.6
	Cloud-based security to prevent unauthorized third-party access	6	18.2
	No direct access for the Flight Operations Department	5	15.2
	Pilot consent required for the use of FDM data in investigations	3	9.1
	Total	33	100.0

Table 4 summarizes participants' evaluations of the strengths and weaknesses of FDM systems, their user-friendliness, and issues related to data privacy and management. The identification of overall trends was the

most frequently reported strength of FDM systems (42.4%), followed by the identification of individual pilot errors (27.3%) and operational errors (18.2%). Systematic pilot errors and individual aircraft-related issues were identified less frequently, accounting for 9.1% and 3.0% of responses, respectively. The risk of data misuse emerged as the most frequently reported weakness of FDM systems (48.5%), while 39.4% of the participants identified inadequate analysis of collected data as a principal limitation. Regarding usability, more than half of the participants (54.5%) described the FDM systems as moderately user-friendly. In comparison, 24.2% considered them not user-friendly, while smaller proportions reported more favorable assessments.

Table 5. Descriptive Findings on FDM Policies, Decision-Making, Pilot Performance, and Training

Variable	Response	n	%
Privacy and Confidentiality Policies	Yes	24	72.7
	No	1	3.0
	Maybe	8	24.2
	Total	33	100.0
Influence on Operational Decision-Making	Significantly influences	4	12.1
	Influences	24	72.7
	Does not influence	5	15.2
	Total	33	100.0
Adjustments to Flying Techniques or Procedures	Yes	18	54.5
	No	15	45.5
	Total	33	100.0
Relationship with Pilot Performance Improvement	Weakly correlated	3	9.1
	Moderately correlated	22	66.7
	Strongly correlated	8	24.2
	Total	33	100.0
Use of FDM Data in Pilot Training	Providing regular updates to flight crews	11	33.3
	Tailoring training to individual pilots	10	30.3
	Updating training syllabi based on FDM events	9	27.3
	Incorporating FDM events into check flights and simulator sessions	1	3.0
	Revising procedures according to operational requirements	2	6.1
	Total	33	100.0

Table 5 presents the findings concerning FDM-related policies, operational decision-making, pilot performance, and training. Most participants (72.7%) reported that policies or procedures addressing the privacy and confidentiality of FDM data were in place within their organization. A further 24.2% were uncertain about the existence of such arrangements, while 3.0% reported that no relevant policies or procedures were available.

FDM was also perceived to influence operational decision-making. While 72.7% of the participants reported that FDM influenced their decision-making processes, 12.1% indicated a significant influence. In contrast, 15.2% reported no influence. In addition, 54.5% of the participants stated that they had made adjustments to their flying techniques or procedures based on insights obtained from FDM data analysis, whereas 45.5% reported no such adjustments. The perceived relationship between FDM data analysis and pilot performance improvement was predominantly moderate to strong. A moderate relationship was reported by 66.7% of the participants and a strong relationship by 24.2%, while 9.1% perceived the relationship as weak. No participant selected the “not correlated” response.

Group-Based Comparisons of FDM Perceptions

Variations in pilots’ perceptions of Flight Data Monitoring (FDM) were examined across selected demographic and professional characteristics. Given the measurement properties of the questionnaire items, group comparisons were conducted using statistical procedures appropriate to the level of measurement of each variable. For ordinal FDM-related variables, differences between commanders and co-pilots were assessed using the Mann–Whitney U test.

The Mann–Whitney U analyses revealed no statistically significant differences between commanders and co-pilots across the ordinal FDM-related variables examined (all $p > .05$). Although some variation was observed in the mean ranks, none of these differences reached statistical significance. Thus, the findings did not indicate a systematic rank-based differentiation in pilots’ evaluations of the examined FDM-related aspects. In contrast, a statistically significant association was identified between current rank and previous FDM training, $\chi^2(1, N = 33) = 9.41, p = .002$. Among commanders, 64.7% (11 of 17) reported having received training on the operation of FDM and its importance for aviation safety, compared with 12.5% (2 of 16) of co-

pilots. Fisher's exact test also indicated a statistically significant association (two-sided $p = .004$). The distribution therefore suggests that previous FDM training was more frequently reported by commanders than by co-pilots in the study sample.

Table 6. Kruskal–Wallis H Test Results for FDM Perceptions by Flight Experience

FDM-related perception	H	df	p
Effectiveness in improving pilot performance and decision-making	1.636	2	.441
Effectiveness in identifying and addressing safety hazards	0.829	2	.661
User-friendliness of FDM systems	3.730	2	.155
Influence on operational decision-making	2.699	2	.259
Perceived relationship with pilot performance improvement	1.853	2	.396

Flight-experience groups were defined as 1–5 years, 6–10 years, and 10 years or more. Statistical significance was evaluated at $p < .05$.

The Kruskal–Wallis H test was used to examine whether selected FDM-related perceptions differed across flight-experience groups. As presented in Table 6, no statistically significant differences were identified for any of the examined variables (all $p > .05$). The largest variation across experience groups was observed for the perceived user-friendliness of FDM systems ($H(2) = 3.73$, $p = .155$); however, this difference did not reach statistical significance. Overall, the findings provide no evidence that the selected FDM perceptions varied systematically according to flight experience within the study sample.

Table 7. Kruskal–Wallis H Test Results for FDM Perceptions by Age

FDM-related perception	H	df	p
Effectiveness in improving pilot performance and decision-making	1.318	3	.725
Effectiveness in identifying and addressing safety hazards	0.533	3	.912
User-friendliness of FDM systems	0.248	3	.969
Influence on operational decision-making	4.792	3	.188
Perceived relationship between FDM data analysis and pilot performance improvement	0.780	3	.854

Discussion, Conclusion and Recommendations

The findings of this study provide a multidimensional view of how pilots perceive Flight Data Monitoring (FDM) within an operational airline environment. Rather than portraying FDM solely as a technical system for recording and analysing flight parameters, the results indicate that pilots associate the system with safety improvement, operational decision-making, performance monitoring, organizational practices, and training. This broader perception is consistent with the contemporary understanding of FDM as a proactive component of an airline's Safety Management System (SMS), through which routine operational data can be transformed into information for identifying emerging hazards, monitoring operational trends, and informing preventive interventions. In this respect, FDM represents a transition from learning primarily from adverse events toward identifying precursors and deviations within normal operations (Walker, 2017; Lager & Melin, 2022).

One of the clearest findings concerns pilots' perceptions of the safety contribution of FDM. Almost all participants (93.9%) reported having observed a specific instance in which FDM data analysis contributed to a safety or operational improvement. In addition, 84.8% rated FDM as either effective or very effective in identifying and addressing safety hazards. These findings suggest that the perceived value of FDM among the participating pilots was grounded in observable operational outcomes rather than being limited to an abstract acceptance of the system. This interpretation is consistent with the proactive safety function attributed to FDM in previous research. Walker (2017) conceptualized FDM as a shift toward the use of leading safety indicators derived from routine operations, while Lager and Melin (2022) emphasized the complementary value of FDM and incident-reporting systems for identifying operational risks before they develop into more serious safety outcomes. Studies based directly on operational flight data have similarly demonstrated that FDM can identify

changes in the frequency and severity of operational occurrences and thereby provide evidence for targeted risk mitigation (Efthymiou et al., 2023).

The perceived contribution of FDM extended beyond hazard identification to pilot performance and operational decision-making. In the present study, 75.8% of participants considered FDM effective or very effective in improving pilot performance and decision-making, while 84.8% reported that FDM influenced or significantly influenced operational decision-making. Moreover, 54.5% indicated that they had adjusted their flying techniques or procedures on the basis of insights obtained from FDM data. These findings are particularly relevant because they point to a potential feedback mechanism through which recorded operational data are translated into behavioral or procedural adaptation. FDM is therefore perceived by many of the participating pilots as having practical implications for subsequent flight operations rather than functioning exclusively as a retrospective monitoring mechanism.

Empirical evidence based on operational FDM data supports the relevance of this connection between monitoring, performance, and training. Research examining the disruption of flight operations during the COVID-19 period demonstrated that FDM data could identify changes associated with manual flying proficiency, procedural practice, and automation-related performance, with the authors emphasizing targeted training as a response to identified risks (Efthymiou et al., 2023a, 2023b). More recently, Balkan et al. (2026) used 15 months of operational FDM data to compare pilots from different training pathways and identified statistically significant differences in several safety-critical flight parameters, including hard landing and long touchdown events. Although these studies analyse actual FDM records rather than pilots' perceptions and therefore cannot be treated as direct validation of the present survey responses, they demonstrate that FDM-derived information can distinguish operational performance patterns that are relevant to training and proficiency.

The organizational dimension of the findings requires a more differentiated interpretation. Although 57.6% of participants considered organizational support for FDM adequate, one-third (33.3%) remained uncertain. Similarly, 42.4% were uncertain about whether barriers to effective FDM implementation existed. These distributions suggest that favorable perceptions of the safety utility of FDM do not necessarily imply equally clear perceptions of the organizational processes surrounding its implementation. This distinction is important because the effectiveness of an FDM programme depends on how data are integrated into organizational safety processes, how findings are communicated, and whether personnel regard the system as a mechanism for learning rather than surveillance or punishment. Lager and Melin (2022), for example, identified organizational and procedural considerations affecting the effective joint use of FDM and incident-reporting systems. More recent evidence from pilots also indicates that reporting behaviour and engagement with safety systems are strongly conditioned by organizational culture. Spragg and Efthymiou (2026) found that Just Culture perception was strongly associated with pilots' willingness to report safety events, whereas demographic characteristics showed no significant association with reporting attitudes.

This organizational interpretation is also consistent with established FDM governance principles. Guidance from the UK Civil Aviation Authority defines FDM as the systematic and proactive use of routine flight data within an intrinsically non-punitive and just safety culture, while current European guidance emphasizes management commitment, non-punitive policies, specialized FDM personnel, confidentiality safeguards, and effective internal communication as characteristics of a mature FDM programme (UK CAA, 2013; EASA, 2026). These principles are relevant to the present findings because uncertainty regarding organizational support or implementation barriers may reflect aspects of FDM governance and communication that are less visible to line pilots, even when the operational safety value of the programme itself is recognized. The present data do not permit identification of the causes of this uncertainty; therefore, such an explanation should be regarded as an interpretive possibility rather than a demonstrated organizational deficiency.

Data privacy and confidentiality constitute another important aspect of FDM acceptance. Nearly half of the participants (48.5%) reported no privacy or confidentiality concerns; however, 45.5% selected an uncertain response. At the same time, 72.7% stated that organizational policies or procedures addressing the privacy and confidentiality of FDM data were in place. When asked how FDM data should be securely managed, 57.6% favored restricting access to the Safety Department and using the data in accordance with established safety procedures. Taken together, these findings indicate that the formal existence of privacy-related policies does not necessarily eliminate uncertainty among pilots regarding the governance and use of FDM data.

This distinction has substantial implications for the functioning of FDM programmes. European FDM guidance requires clear procedures concerning data access, security, retention, crew feedback, confidentiality, and the circumstances under which remedial training may be initiated; importantly, such training is expected to be constructive and non-punitive (EASA, 2026). The importance of these safeguards is also supported by empirical studies of pilot reporting behaviour. Kiouleoglou et al. (2025) found that fear of blame, stigmatization, and concerns regarding career progression were prominent barriers to incident reporting among pilots, while participants emphasized the importance of trustworthy reporting systems and Just Culture. Spragg and Efthymiou (2026) likewise showed that pilots' perception of Just Culture was more closely associated with reporting willingness than demographic characteristics. Although voluntary reporting and FDM are distinct safety mechanisms, they share an important organizational requirement: pilots must have confidence in how safety information is collected, protected, interpreted, and subsequently used. The training-related findings reveal an important contrast. Although participants generally evaluated FDM favorably, 60.6% reported that they had not received specific training concerning how FDM operates and its importance for aviation safety. Moreover, previous FDM training was significantly associated with current rank: 64.7% of commanders reported having received such training, compared with 12.5% of co-pilots, $\chi^2(1, N = 33) = 9.41$, $p = .002$; Fisher's exact $p = .004$. This was the clearest group-based association identified in the study. The finding should not be interpreted as evidence that rank itself causes differences in access to FDM training, as rank is likely to covary with seniority, organizational responsibilities, previous training opportunities, and other unmeasured professional factors. Nevertheless, the magnitude of the observed difference indicates a potential imbalance in pilots' exposure to formal FDM education within the study setting.

This result deserves particular attention because effective use of FDM depends on more than the technical collection of flight data. Pilots need to understand the purpose of monitoring, how events and trends are interpreted, how data are protected, and how FDM findings feed back into safety and training processes. Regulatory guidance accordingly identifies staff training, communication, data protection, and constructive feedback as integral elements of FDM implementation (UK CAA, 2013; EASA, 2026). The training implication is also consistent with empirical evidence demonstrating the potential of FDM data to inform targeted interventions. Efthymiou et al. (2023a) argued for tailored training in response to operational risks identified through FDM, while Balkan et al. (2026) demonstrated that FDM metrics can reveal performance differences associated with different pilot training pathways. The present study extends this discussion from operational FDM outcomes to pilots' exposure to FDM education itself and suggests that access to such training may warrant greater organizational attention, particularly among co-pilots.

Finally, the absence of statistically significant differences in the selected ordinal FDM perceptions across age, flight experience, and rank provides an additional perspective on the findings. The results do not establish equivalence between demographic or professional groups, particularly given the limited sample size; rather, they indicate that this study did not detect systematic group-based differences in the evaluated FDM perceptions. This pattern is broadly consistent with recent evidence suggesting that attitudes toward aviation safety systems may be influenced more strongly by organizational and cultural conditions than by individual demographic characteristics. Spragg and Efthymiou (2026), in a study of 117 commercial airline pilots, similarly found no significant role for demographic characteristics in reporting attitudes and emphasized the stronger relevance of Just Culture perception. Taken together, the findings suggest that the central issue may be less whether pilots of different ages, experience levels, or ranks perceive the technical and operational value of FDM differently, and more how the organization converts FDM into a trusted and accessible learning process. The coexistence of broadly favorable safety and performance evaluations with comparatively limited formal FDM training, uncertainty regarding organizational support and implementation barriers, and substantial uncertainty regarding privacy and confidentiality points to an important distinction between the perceived utility of FDM and the organizational conditions under which that utility is realized. For airlines, the effectiveness of FDM may therefore depend on combining technically robust data analysis with transparent governance, equitable training opportunities, protected data use constructive feedback, and a credible non-punitive safety culture

Acknowledgements

The authors would like to express their sincere appreciation to all pilots of Air Albania who contributed to the development of this study. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions

Author 1: Conceptualization, Methodology, Formal Analysis, Writing, Project Administration.

Author 2: Supervision, Project Administration, Review & Editing.

Author 3: Data Curation, Validation, Resources, Review & Editing.

Author 4: Methodology, Writing, Resources, Review & Editing.

Declaration of Interest

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

Ethical approval

The ethics committee report for this study was approved by the Ethics Committee of the Rectorate of Eskisehir Technical University pursuant to Decision No. E-87914409-050.04-94948 dated August 14, 2025.

Reference

- Aksoy, E. (2006). *The human factor in ensuring flight safety and the importance of vocational training in this process* [In Turkish]. Istanbul University Institute of Social Sciences.
- Bakır, M., Bal, H. T., & Akan, Ş. (2017). Evaluation of the Turkish civil aviation sector using an integrated SWOT-AHP approach [In Turkish]. *Journal of Aviation*, 1(2), 154–169.
- Balkan, M. O., Soran, S., Gunessen, N. M., & Yildirim, G. (2026). A quantitative analysis of the impact of traditional vs. MPL (Multi-Crew Pilot License) training pathways on operational performance: A 15-month FDM data study. *Human Factors in Aviation and Aerospace*, 3(1), 34–42. doi:10.26650/hfaa.2026.1893289
- Başak, H., & Gülen, M. (2008). A risk assessment and management model for preventing unmanned aerial vehicle accidents [In Turkish]. *Mühendislik Bilimleri Dergisi*, 14(1), 55–65.
- Başdemir, M. M. (2020). *Crew resource management for all aviation professionals* [In Turkish]. Beta Publishing.
- Bayat, B. (2008). The strategic nature of human resource management [In Turkish]. *Gazi University Journal of Economics and Administrative Sciences*, 10(3), 67–91.
- Birgören, N. (2015). *A study on the effects of crew resource management practices on cabin crew from a flight safety perspective* [Master's thesis, Istanbul Gelisim University Institute of Social Sciences].
- Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quinonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: A primer. *Frontiers in Public Health*, 6, Article 149. doi:10.3389/fpubh.2018.00149
- Büyüköztürk, Ş. (2017). *Handbook of data analysis for social sciences* [In Turkish]. Pegem Academy.
- Campbell, J., & Jardine, A. (2001). *Maintenance excellence*. Marcel Dekker.
- Canarslanlar, A. O. (2015). *Hava trafik yönetiminin uçaklarda yakıt tüketimi ve emisyonu olan etkilerinin gerçek uçuş verilerine dayalı analizi ve bir model önerisi* [Doctoral dissertation, Anadolu University].
- Ceruti, P., Marzocca, A., Liverani, A., & Bil, C. (2019). Maintenance in aeronautics in an Industry 4.0 context: The role of augmented reality and additive manufacturing. *Journal of Computational Design and Engineering*, 6, 516–526.
- Chrysanthos, V. (2014). *Kernel methods for flight data monitoring* [Doctoral dissertation, Massachusetts Institute of Technology].

- Davis, J. R., Johnson, R., & Stepanek, J. (Eds.). (2008). *Fundamentals of aerospace medicine*. Lippincott Williams & Wilkins.
- Endsley, M. R. (1999). Situation awareness in aviation systems. In J. Wise, D. Hopkin, & D. Garland (Eds.), *Handbook of aviation human factors* (pp. 257–276). Lawrence Erlbaum Associates.
- European Aviation Safety Agency. (2012). *Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council*.
- European Aviation Safety Agency. (2020). *Guidance for the implementation of flight data monitoring precursors*.
- European Union Aviation Safety Agency. (2026). *Easy Access Rules for Air Operations* (Revision 24, March 2026). EASA.
- Gao, S., Wang, L., Zhang, N., Bai, Y., Tian, Y., Chen, S., Zhang, Y., & Zhou, H. (2025). Pilot flying versus pilot monitoring: The effect of role assignment on pilots' perceived risk in flight simulation experiment. *Risk Analysis*, 45(9), 2759–2770. doi:10.1111/risa.70048
- Gemici, E., & Yılmaz, H. (2019). Aviation security in terms of security strategies and management [In Turkish]. *Journal of Aviation*, 3(1), 15–27. doi:10.30518/jav.550123
- Hartzler, B. M. (2014). Fatigue on the flight deck: The consequences of sleep loss and the benefits of napping. *Accident Analysis & Prevention*, 62, 309–318.
- International Civil Aviation Organization. (2018). *Annex 6 to the Convention on International Civil Aviation: Operation of aircraft, Part I—International commercial air transport—Aeroplanes* (11th ed.). ICAO.
- International Civil Aviation Organization. (2022). *Safety management manual (SMM)* (Doc 9859, 5th ed.). ICAO.
- Karaoğlu, A. C. (2021). Maintenance, repair and overhaul activities in civil aviation, Aviation 4.0 and emerging trends [In Turkish]. *Manufacturing Technologies and Applications*, 2(1), 61–74.
- Keleş, A., & Keleş, A. (2018). Innovations and challenges brought by the Internet of Things [In Turkish]. *Electronic Turkish Studies*, 13(13).
- Kiouloupoglou, P., Nikolaidis, V., David, K. M., & Makris, I. (2025). Investigating incident under-reporting in aviation: Qualitative insights among Greek pilots. *Research in Transportation Business & Management*, 59, Article 101309. doi:10.1016/j.rtbm.2025.101309
- Korul, V., & Küçükönel, H. (2003). Structural analysis of the Turkish civil aviation system [In Turkish]. *Ege Academic Review*, 3(1), 24–38.
- Krajček, K., Nikolić, D., & Domitrović, A. (2015). Aircraft performance monitoring from flight data. *Technical Gazette*, 22(5), 1337–1344. doi:10.17559/TV-20131220145918
- Lager, E., & Melin, M. (2022). Proactive flight safety—A feasibility study on optimal use of flight data monitoring and incident reports in an airline. *International Journal of Occupational Safety and Ergonomics*, 28(2), 1311–1315. doi:10.1080/10803548.2021.1899608
- Li, L. (2013). *Anomaly detection in airline routine operations using flight data recorder data* [Doctoral dissertation, Massachusetts Institute of Technology].
- Li, L., Das, S., Hansman, R. J., Palacios, R., & Srivastava, A. N. (2015). Analysis of flight data using clustering techniques for detecting abnormal operations. *Journal of Aerospace Information Systems*, 12(9), 587–598.
- Li, L., Hansman, R. J., Palacios, R., & Welsch, R. E. (2016). An incremental clustering method for anomaly detection in flight data. *Journal of Aerospace Information Systems*, 13(12), 464–481.
- Oehling, J., & Barry, D. J. (2019). Using machine learning methods in airline flight data monitoring to generate new operational safety knowledge from existing data. *Aerospace*, 6(6), Article 62. doi:10.3390/aerospace6060062
- Oğuz, A. K. (2015). Aviation medicine and hypertension [In Turkish]. *TKS*, 15(3).

- Scarinci, A. (2017). *Monitoring safety during airline operations: A systems approach* [Master's thesis, Massachusetts Institute of Technology].
- Simpson, P. (2001). *Naturalistic decision making in aviation environments*. DSTO Aeronautical and Maritime Research Laboratory.
- Spragg, D., & Efthymiou, M. (2026). Airline pilots' perception of Just Culture and their willingness to submit safety reports within the context of flight data monitoring (FDM). *Transportation Research Interdisciplinary Perspectives*, 39, Article 102207. doi:10.1016/j.trip.2026.102207
- Sullivan, G. M., & Artino, A. R., Jr. (2013). Analyzing and interpreting data from Likert-type scales. *Journal of Graduate Medical Education*, 5(4), 541–542. doi:10.4300/JGME-5-4-18
- Şen, M., Dalcı, A., & Temurtaş, F. (2020). Past, present, and future trends of technologies used in the aviation industry [In Turkish]. *Journal of Intelligent Transportation Systems and Applications*, 3(2).
- Tutkun, A., & Bilal, Ç. (2025). Industry 4.0 and smart operational systems in the aviation sector [In Turkish]. In A. Tutkun (Ed.), *Global trends and strategic directions in air transportation* (pp. 1–24). Nobel Academic Publishing.
- UK Civil Aviation Authority. (2013). *CAP 739: Flight data monitoring*. Civil Aviation Authority.
- Walker, G. H. (2017). Redefining the incidents to learn from: Safety science insights acquired on the journey from black boxes to flight data monitoring. *Safety Science*, 99, 14–22. doi:10.1016/j.ssci.2017.05.010
- Wang, B., Liu, D., Peng, Y., & Peng, X. (2019). Multivariate regression-based fault detection and recovery of UAV flight data. *IEEE Transactions on Instrumentation and Measurement*, 69(6), 3527–3537.
- Warner, P. (2013). Testing association with Fisher's exact test. *Journal of Family Planning and Reproductive Health Care*, 39(4), 281–284. doi:10.1136/jfprhc-2013-100747
- Yavuz, İ. (2013). THK Etimesgut aircraft factory (1939–1950) [In Turkish]. *Mühendis ve Makina*, 32–36.
- Zhao, Y., Li, L., Alam, S., & Wang, J. (2021). An incremental clustering method for anomaly detection in flight data. *Transportation Research Part C: Emerging Technologies*, 129, Article 103236.