Transportation Research Part A 206 (2026) 104904

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

PREVENTing Pilot murder-suicide: A policy-oriented review

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A R T I C L E I N F O

Keywords:
Air transportation
Pilot
Suicide

A B S T R A C T

Pilot murder-suicides represent a critical and under-addressed challenge at the intersection of human factors, safety management, and intelligent transportation systems. Recent high-profile incidents–such as Mozambique Airlines Flight 470 (2013), Germanwings Flight 9525 (2015), China Eastern Airlines Flight 5735 (2022), and preliminary discussions around Air India Flight 171 (2025)–have underscored the urgent need for evidence-based prevention strategies that align with the evolving landscape of smart and automated aviation. While substantial primary research exists, the field lacks a comprehensive, policy-oriented synthesis that bridges psychological, operational, and technological dimensions. To address this gap, we consolidate the extant literature and introduce the PREVENT framework, a multidimensional, data-driven approach to mitigating pilot murder-suicide risks. The framework spans seven prevention domains, offering actionable insights for integrating mental health support, real-time risk monitoring, and human-centered design into next-generation aviation systems. By synthesizing empirical evidence and case studies, this review provides a roadmap for policymakers, transport authorities, and industry practitioners to enhance safety in intelligent aviation environments. We identify conceptual and empirical gaps to guide future research, emphasizing the need for interdisciplinary collaboration between behavioral science, engineering, and public policy to ensure safe, resilient, and human-focused smart transportation systems.

1. Introduction

Since the mid-20th century, aviation safety has witnessed remarkable advancements, largely driven by significant technological innovations (Gill, 2004; Kim, 2004; Jr et al., 2013; Wandelt et al., 2025). The introduction of jet engines in the 1950s marked a significant shift, offering greater reliability and efficiency compared to piston engines, which substantially reduced the risk of engine-related failures (Fromm, 1968; Tye, 1980). The subsequent development of advanced avionics, including the adoption of inertial navigation systems and later GPS technology, revolutionized flight navigation, minimizing human error and enhancing situational awareness for pilots (Migneault, 1980; Jr et al., 2013). The advent of digital technology brought about another leap in aviation safety through the implementation of advanced communication systems, such as the Aircraft Communications Addressing and Reporting System (ACARS), which facilitated real-time data exchange between aircraft and ground stations (Roy, 2001). Additionally, the

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https://doi.org/10.1016/j.tra.2026.104904

Available online 11 February 2026

integration of Traffic Collision Avoidance Systems (TCAS) and Enhanced Ground Proximity Warning Systems (EGPWS) has been instrumental in preventing mid-air collisions and controlled flight into terrain accidents, respectively (Breen, 2002; Harman, 1989; Williamson and Spencer, 1989). These systems provide pilots with critical alerts and guidance to avoid potential hazards, underscoring the proactive approach to safety management, reducing the likelihood of catastrophic failures and impact on the society (Lirn and Sheu, 2009).

With advances in aircraft design, automation, and maintenance substantially reducing technical-failure risk, residual safety risk increasingly reflects human factors–most notably human error and rare but catastrophic events such as pilot-perpetrated murder-suicide (Gambetta, 2005). The remarkable progress in aircraft reliability and system redundancies has created an environment where the likelihood of accidents due to mechanical failures is substantially reduced. Consequently, the aviation industry has turned the attention to the complexities of human behavior and mental health, recognizing these as critical components in the pursuit of comprehensive aviation safety (Bor et al., 2002; Wu et al., 2016). The phenomenon of pilot suicide, although rare, has had a profound impact on the aviation community and the public consciousness, especially when these tragic events result in the loss of innocent lives (Phillips, 1978, 1980). One of the most notable and devastating examples is the case of Germanwings Flight 9525 in 2015, where the co-pilot deliberately crashed the aircraft into the French Alps, killing all 150 people on board (Pasha et al., 2018). Investigations revealed that the co-pilot had a history of psychological issues, including depression, and had concealed his mental health condition from his employer. The incident prompted international discussion about strengthening aviation policies to address mental health and its systemic causes, including fair screening processes, confidentiality protections, and accessible supports for pilots and crews (Politano and Walton, 2016; Soubrier, 2016). Most recently, on June 12, 2025, Air India Flight 171, a scheduled international passenger flight from Ahmedabad to London Gatwick, crashed approximately 30 seconds after takeoff, resulting in the deaths of 230 passengers and all 12 crew members (Elhamahmy and Gohar, 2025). The crash occurred in a residential area near Ahmedabad Airport. Preliminary investigations revealed that fuel-control switches were cut, although the reason for this action remains unexplained. The aircraft, a Boeing 787-8 Dreamliner, reached an altitude of 625 feet before losing location data and crashing. The investigation, involving multiple agencies including India's Directorate General of Civil Aviation and international experts, continues to explore the circumstances surrounding the crash. A preliminary report suggests that one of the two pilots might have manually cut off fuel for the engines during takeoff, leading to speculation that this potentially is one of the deadliest murder-suicide cases in aviation[1][2][3]. Other sources consider a full electrical breakdown of the aircraft as major reason for the fatal crash.

In this study, we undertake a comprehensive examination of the available academic literature regarding the issue of pilot murder-suicide cases, leveraging mainly a narrative review approach. Our analysis is structured around seven critical aspects, each representing a distinct dimension of the problem and collectively forming the so-called PREVENT framework, an acronym constructed from the initial letters of each aspect. Specifically, we explore policy and regulatory oversight to understand the legal and administrative measures currently in place. We assess risk factors and their evaluation methodologies to identify precursors and warning signs. The role of education and training is scrutinized to determine its effectiveness in preparing personnel to handle such crises. We delve into vigilance /monitoring practices to evaluate their efficacy in preempting incidents. Enhanced mental health support is analyzed to gauge the adequacy of psychological assistance available to pilots. We also investigate efforts aimed at normalizing health problems and reducing stigma associated with mental health issues in the aviation sector. Lastly, we examine technological solutions that could potentially mitigate the risk of such tragic events. Through our PREVENT framework, our study aims to provide a holistic understanding of state of the art in the extant literature and the challenges / integrated strategies to address this pilot muder-suicide cases in aviation safety.

The remainder of this study is structured as follows. Section 2 discusses recent suspected and confirmed murder-suicides cases in air transportation. Section 3 introduces our framework of seven dimensions. Section 4 discusses managerial insights and proposes various directions for future work. Section 5 concludes this study.

2. Murder-suicides cases in air transportation

In this section, we review suspected and confirmed murder-suicides cases in air transportation. Generally speaking, aircraft crash investigations can be considered among the most intricate and complex fields within aviation safety, since they require a comprehensive analysis of various technical, human, and environmental factors (yer et al., 2012; O'hare et al., 1994; Vuorio et al., 2014b). When suspicions of pilot murder-suicide arise, the complexity of these investigations increases significantly: Proving that a pilot deliberately caused a crash necessitates not only technical evidence but also psychological and behavioral analysis, which is often complicated by the lack of direct witnesses and the pilot's demise (Kenedi et al., 2016; Soubrier, 2016; Vuorio et al., 2023). The International Civil Aviation Organization (ICAO) mandates a structured approach to accident investigation, involving multiple international parties such as the states of occurrence, registry, operator, design, and manufacture, each contributing expertise and data, ultimately ensuring a comprehensive examination of all possible causes (Agustini et al., 2021; Huang, 2009). Mechanical failures encompass any malfunction or structural failure in the aircraft that could lead to catastrophic events. Investigators meticulously examine components such as engines, fuel systems, flight controls, and avionics. Human error is the leading cause of aviation accidents, accounting for a significant percentage of major airline crashes. The Swiss cheese model, a widely accepted accident causation model, illustrates

[1] https://www.bbc.com/news/articles/cn9yw0rljwvo
[2] https://www.wsj.com/world/asia/air-india-crash-senior-pilot-eab72db5
[3] https://www.ft.com/content/8dc9f1cf-dfee-4cd5-99b0-f5aed9d2a659

Table 1
Suspected and confirmed murder-suicides cases in commercial aviation.

Year	Location	Aircraft type	Fatalities	Description	Type
1982	Tokyo Bay, Japan	McDonnell Douglas DC-8	24	Pilot engaged thrust reversers in flight, crashed into Tokyo Bay	Confirmed
1994	Near Agadir, Morocco	ATR 42–300	44	Pilot locked co-pilot out of cockpit and crashed aircraft	Confirmed
1997	Musi River, Indonesia	Boeing 737-300	104	Controversial crash with Indonesian authorities undetermined	Suspected
1999	Atlantic Ocean, USA	Boeing 767-300	217	Relief first officer disengaged autopilot and shut down engines	Confirmed
2014	Indian Ocean	Boeing 777-200ER	239	Flight disappeared, likely deliberately flown off course	Suspected
2015	French Alps	Airbus A320	150	Co-pilot locked captain out, crashed aircraft into mountain	Confirmed
2022	Guangxi, China	Boeing 737–800	132	No public final report, cause not officially determined	Under investigation
2025	Ahmedabad, India	Boeing 787-8 Dreamliner	242	Preliminary finding of dual fuel cutoff, deliberate action unsubstantiated	Under investigation

how multiple layers of defenses–organizational, supervisory, preconditions, and unsafe acts–must be analyzed to understand how an accident occurred (Bergeon and Hensley, 2009; Shabani et al., 2024). Investigators must assess pilot training, fatigue, mental health, and adherence to protocols. Environmental / meteorological conditions, such as adverse weather, often play another crucial role in aircraft crashes (Mazon et al., 1967). Investigators analyze meteorological data to determine if weather conditions contributed to the accident. This includes reviewing radar data, weather reports, and witness statements.

To formally conclude that a crash was a deliberate act by the pilot, investigators must amass substantial evidence, including suicide notes, documented mental health issues, previous suicide attempts, or explicit threats. However, direct evidence is often scarce or absent, making it difficult to conclusively prove intent. Investigators must rely on circumstantial evidence, such as cockpit recordings, flight data, and witness statements, which may not always provide a clear picture. Psychological evaluations are critical in assessing the mental health of pilots and identifying potential risks. These evaluations include reviews of medical records, interviews with family and colleagues, and psychological autopsies that reconstruct the pilot's mental state (Bor et al., 2002). However, psychological assessments are not foolproof, since pilots may conceal mental health issues due to fear of losing their medical certification or job (Chaimowitz et al., 2023). Reconstructing the events leading to a crash in cases of suspected pilot murder-suicide is complex. Investigators must piece together data from flight recorders, cockpit voice recordings, and witness accounts. The interpretation of cockpit voice recordings requires expertise from linguists, psychologists, and aviation specialists to understand the pilot's mental state and actions (Deepak, 2019). The absence of direct witnesses and the pilot's death further complicates the reconstruction.[2]

Several high-profile cases illustrate the complexities and evolution of investigations involving pilot murder-suicide. These cases underscore the critical importance of rigorous mental health evaluations and robust safety protocols in aviation. One of the earliest recorded cases is Japan Airlines Flight 350 in 1982. Captain Seiji Katagiri, diagnosed with paranoid schizophrenia, was deemed fit to fly after treatment. On February 9, 1982, he deliberately crashed the plane into Tokyo Bay, killing 24 passengers. Katagiri's premature reinstatement highlighted flaws in psychological screening (Deepak, 2019; Schmid, 2018a). In 1994, Royal Air Maroc Flight 630 was crashed by Captain Younes Khayati into the Atlas Mountains, driven by personal despair. Despite his experience, the tragedy emphasized the need for comprehensive mental health screening (Mulder and Rooy, 2018). SilkAir Flight 185 crashed in 1997, likely due to deliberate actions by Captain Tsu Way Ming, who had personal conflicts and procedural violations. The crash remains controversial due to inconclusive evidence (Marks, 2014; Mattson, 2015). EgyptAir Flight 990 crashed in 1999 after relief first officer Gameel Al-Batouti, who had mental health issues, disengaged the autopilot. The cause remains disputed, marking it the deadliest Boeing 767 disaster. Malaysia Airlines Flight 370 disappeared in 2014, with investigations suggesting deliberate actions by Captain Zaharie Ahmad Shah, who had personal issues. The lack of wreckage recovery complicated the investigation, highlighting the need for improved safety protocols (Ashari et al., 2017; Ashton et al., 2015; Mcnutt, 2014; Nile, 2017). The 2015 Germanwings Flight 9525 crash was caused by the co-pilot, who concealed severe depression. The investigation revealed significant shortcomings in mental health protocols and cockpit security. In 2022, China Eastern Airlines Flight 5735 crashed due to deliberate flight control manipulation. The ongoing investigation faces challenges due to terrain and weather, emphasizing the need for transparency (Du et al., 2025; Parker, 2022; Vuorio et al., 2024). In 2025, Air India Flight 171 crashed after manual fuel cutoff, with investigations suggesting pilot involvement. This incident raises questions about mental health screening and has led to mass leave by pilots, highlighting aviation safety concerns.

Taken together, suspected and confirmed pilot-perpetrated crashes remain exceedingly rare yet uniquely consequential. Attribution of intent is often contested and should rest on convergent technical, behavioral, and contextual evidence rather than post hoc inference. Across cases, risk reflects an interaction of individual factors and system determinants (organizational, regulatory, operational) rather than 'mental health' alone. Patterns include cockpit-access policies, return-to-work decisions, reporting and confidentiality rules, workload and fatigue, and media dynamics. Accordingly, prevention should emphasize multi-level controls–evidence-based clinical pathways and peer/support programmes, just-culture reporting, fitness-for-duty governance, and design/operational barriers–while recognizing the limits of prediction and the need for transparent, timely investigations.

3. The PREVENT framework

There is a rich set of primary studies concerning pilot murder-suicide cases, investigation this phenomenon from different perspectives. Below, we discuss the extant literature on the subject in a narrative review regarding seven distinct aspects: policy / regulatory oversight (Section 3.1), risk factors and their assessment (Section 3.2), education/ training (Section 3.3), vigilance / monitoring (Section 3.4), enhanced mental health support (Section 3.5), normalizing health problems / reducing stigma (Section 3.6), and tech-

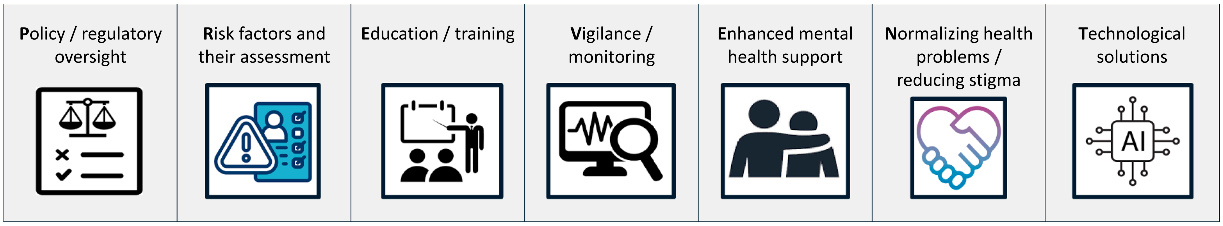

Fig. 1. Overview on the PREVENT framework.

Table 2
Tabular overview on the PREVENT framework.

Category	Key Focus Areas	Main Goals
Policy / Regulatory Oversight	Transparent reporting, international oversight, support systems, continuous education, post-incident investigations, regular psychological assessments, global standards, collaboration, crew training, regulatory comparison	Create a supportive regulatory environment, enhance data-driven policymaking, and ensure global consistency in mental health support.
Risk Factors and Their Assessment	Mental health issues, stigma & regulatory barriers, psychological factors, media influence, occupational stressors, systemic analysis, interrelationships	Identify and mitigate risk factors, reduce stigma, and understand the complex interrelationships of psychological and occupational stressors.
Education / Training	Mental health awareness, targeted support, psychological evaluations, proactive risk management, digital self-management tools, biofeedback techniques, specialized training, warning sign recognition	Equip aviation personnel with mental health knowledge, reduce stigma, and foster a culture of proactive mental health management.
Vigilance / Monitoring	High-risk periods, anonymous surveys, comprehensive screenings, digital tools, AI-based monitoring, wearable devices, data integration	Monitor mental health in real time, detect early signs of distress, and integrate digital tools for proactive intervention.
Enhanced Mental Health Support	Peer-support programs, cognitive behavioral therapy, standardized psychological tests, crisis intervention, work-related stressors, recovery & training, psychological reports, medical training	Provide accessible and effective mental health support, foster a culture of openness, and ensure timely crisis intervention.
Normalizing Health Problems / Reducing Stigma	Transparent communication, anonymous assessments, peer support programs, real-time assessments, supportive workplace culture	Normalize mental health discourse, reduce stigma, and encourage help-seeking behavior through transparent communication and supportive workplace culture.
Technological Solutions	Wearable devices, AI algorithms, sentiment analysis, psychological screening tools, psychosocial reconstruction, ground-based support, automation & redundancy, ethical frameworks, crew scheduling systems	Leverage technology for real-time monitoring, enhance safety through automation, and ensure ethical use of data and privacy protection.

nological solutions (Section 3.7). Overall, the initial characters of these seven aspects build the acronym PREVENT; therefore, we refer to our dissection of the extant literature and the highlighted challenges as the PREVENT framework; visualized in Fig. 1.

We believe that our framework addresses the most critical and predominant aspects of this complex issue. Policy and regulatory oversight were included to ensure robust, standardized guidelines that govern pilot mental health, fitness-to-fly assessments, and accountability–foundational elements in systemic prevention. Risk factors and their assessment form the core of proactive intervention, enabling early identification of individuals at risk through evidence-based screening. Education and training empower aviation professionals to recognize warning signs and respond effectively, fostering a culture of awareness. Vigilance and monitoring provide ongoing oversight, ensuring that potential risks are continuously evaluated. Enhanced mental health support offers accessible, specialized care, addressing the root causes of distress. Normalizing health problems and reducing stigma encourages open dialogue, making it safer for individuals to seek help without fear of repercussions. Finally, technological solutions–such as advanced screening tools and data analytics–augment human efforts, creating a multi-layered defense. Together, these seven categories form a comprehensive, holistic approach, covering the psychological, operational, and systemic dimensions essential to preventing such tragedies. Tab. 3 provides a summary of the PREVENT framework.

3.1. Policy / regulatory oversight

In the aviation industry, policy and regulatory changes are essential to creating an environment that protects both public safety and pilot well-being. Transparent reporting and standardized investigative methodologies allow aviation authorities to generate robust data, supporting evidence-based policymaking. International bodies and organizations can strengthen oversight by adopting multifaceted approaches that address pilot mental health and its systemic causes through proactive risk management, fair evaluation protocols, and supportive policies. Robust support systems can be facilitated through international regulatory frameworks, ensuring pilots have access to confidential mental health services, crisis management protocols, and non-punitive reporting mechanisms (Dehoff and Cusick, 2018; Lewis et al., 2007; Rice and Sher, 2016). International organizations also play a key role in promoting continuous education and open communication about mental health, helping to reduce stigma and encourage help-seeking (Bor et al., 2024; Eriksen and Bor, 2016); see Section 3.3 and Section 3.6. Similarly, regulatory requirements for post-incident investigations and, where appropriate, psychological autopsies can facilitate interdisciplinary analyses of pilot well-being and contextual stressors, generating insights to improve preventive strategies (Ast et al., 2001; Cullen, 1998; Günther et al., 1999).

One frequently proposed measure is the introduction of regular, structured assessments of pilots' psychological well-being, substance use, and relevant life stressors (Dehoff and Cusick, 2018; Lewis et al., 2007; Rice and Sher, 2016). However, it remains uncertain whether existing tools can reliably define what it means to be "fit to fly" from a psychological perspective. Unlike technical failures, psychological vulnerabilities are dynamic, context-dependent, and shaped by systemic factors such as organizational culture, workload, and regulatory pressures. Consequently, international aviation authorities, including the FAA, should support policies that integrate assessments within broader system-level interventions, ensuring that measures are non-punitive and do not deter disclosure. Rather than relying on zero-tolerance approaches, more effective strategies combine screening with sustained support, stigma reduction, and organizational reforms (Botch and Johnson, 2009; Kaplan, 1966). Establishing harmonized global standards for mental health assessments and support systems–together with mechanisms for cross-border collaboration–would enhance fairness, consistency, and effectiveness in regulatory oversight (Etschmaier and Lee, 2016; Haldorsen et al., 2002; Ungs, 1994). Collaboration and data sharing among international bodies are especially important for identifying emerging risks and enabling early intervention. Complementary measures such as crew training in recognizing distress, confidential well-being briefings, and accessible peer support programmes can reinforce formal regulations (Bor and Hubbard, 2016; Cahill et al., 2019; Laukkala et al., 2018).

As aviation authorities worldwide grapple with how to keep both pilots and passengers safe, comparing the approaches of the FAA (US), EASA (EU), and CASA (Australia) reveals where global standards could improve. The US is in the midst of a major overhaul, with the 2025 Mental Health in Aviation Act[4] pushing to remove barriers that discourage pilots from seeking help - like the fear of losing their medical certification. The focus is on updating policies, expanding treatment options, and launching campaigns to break down stigma. Meanwhile, Europe's EASA has taken a more structured approach, mandating psychological assessments and peer-support programs after the Germanwings tragedy. Their policies are backed by ongoing research, aiming for consistency across EU countries and a focus on functional fitness rather than blanket restrictions. Australia's CASA, on the other hand, leans toward a risk-based, flexible model, emphasizing confidentiality and practical return-to-work solutions. In summary, the US and EU are leading with bold reforms - legislative in the US, research-driven in Europe - while Australia's approach offers a reminder that flexibility and trust can also foster a safer, healthier aviation culture. This comparison could help the industry to build better support plans.

In summary, while no single measure can eliminate the risk of pilot-perpetrated events, regulatory oversight provides a critical framework for aligning technical, organizational, and psychological safeguards. Achieving international consensus remains challenging, but also represents an opportunity to build coordinated, evidence-based systems that simultaneously enhance aviation safety and support pilot well-being.

3.2. Risk factors and their assessment

The identification and assessment of risk factors is fundamental in preempting pilot murder-suicide. Aviation authorities must analyze various factors contributing to mental health issues among pilots, including occupational stress, work environment, and personal challenges. Advanced analytical tools enable the identification of at-risk individuals, facilitating early intervention strategies. The risk factors that increase the likelihood of pilot murder-suicides in air transport are multifaceted and interconnected, stemming from a combination of psychological, social, and occupational stressors. One of the most significant risk factors is the high prevalence of mental health issues among pilots, particularly depression. Studies have shown that up to 12.6% of pilots experience depression, and around 4.1% have suicidal thoughts (Pasha et al., 2018; Wu et al., 2016). These mental health struggles are often exacerbated by occupational stressors unique to the aviation industry, such as disrupted circadian rhythms, fatigue, and social isolation (Cahill et al., 2018; Johansson and Melin, 2018; Jones, 1977). Additionally, pilots face intense performance pressure and high-stress environments, which can significantly contribute to their psychological distress (Clarke, 2023). At the same time, efforts to identify and assess risk must be carefully balanced with the protection of pilots' privacy and confidentiality, ensuring that sensitive health information is safeguarded and used solely for supportive–not punitive–purposes, thereby upholding human dignity and sustaining trust in the aviation system.

Another critical risk factor is the stigma associated with mental illness within the aviation industry, which often prevents pilots from seeking help due to fears of career repercussions (Hubbard, 2016; Sachs, 2023). This stigma is compounded by regulatory

[4] https://www.congress.gov/bill/119th-congress/house-bill/2591/text

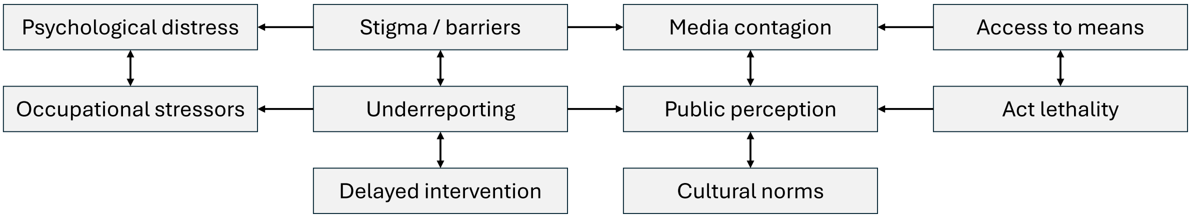

Fig. 2. Interdependencies between risk factors.

barriers, such as license disqualification and medical suspension, that discourage disclosure of mental health symptoms (Chaimowitz et al., 2023); see Section 3.6 for a detailed discussion. The underreporting of mental health issues is a substantial concern, as it hinders early intervention and support (Yanowitch et al., 1973). Moreover, the absence of comprehensive mental health screening and continuous evaluation processes exacerbates the underassessment of these risks (Sycher, 2013). As mentioned earlier, structured screening may form part of the solution, but it must be implemented in ways that respect privacy, protect confidentiality, and foster a culture where seeking help is viewed as a strength rather than a liability.

Specific psychological factors, such as personality disorders, substance abuse, and a history of negative life events, have also been identified as significant risk factors (Butcher, 2002; Mulder and Rooy, 2018; Patterson et al., 2001; Vuorio and Bor, 2020). The system theoretic accident modelling and process provides a holistic approach to identify and mitigate risk factors, emphasizing the need for balanced regulations that address both medical privacy and public safety (Schmid, 2018b; Schmid et al., 2018). The influence of critical events, such as financial stress and economic threats, has been highlighted as a potential trigger for pilot suicides, particularly during crises like the COVID-19 pandemic (Abeyratne, 2000; Vuorio and Bor, 2020). Media coverage and public perception play a crucial role in exacerbating risk factors. Highly publicized murder-suicides can lead to a "copycat" effect, increasing the likelihood of similar incidents (Altheide, 1981; Phillips, 1978, 1980). Relatedly, the intensity of media publicity and the portrayal of pilots' mental health in the media can significantly influence public risk assessment and the behavior of vulnerable pilots (Rice et al., 2015; Winter and Rice, 2015; Yanowitch et al., 1973). Research on suicide contagion suggests that repeated or sensationalized coverage of high-impact events can unintentionally normalize or even glamorize such acts, thereby amplifying risk among vulnerable individuals. In aviation, this effect is particularly difficult to contain because crashes are rare, catastrophic, and highly newsworthy, which ensures extensive international coverage. The challenge for regulators and media alike is to balance the public's right to information with responsible communication strategies that minimize harm–avoiding glorification, oversimplification, or pathologizing narratives that may reinforce stigma or trigger imitation. Moreover, the physical availability and personal evaluation of the method influence the choice of suicide methods among pilots (Lester, 2017). In summary, the risk factors for pilot murder-suicides in air transport are a complex interaction of high prevalence of mental health issues, occupational stressors, stigma and regulatory barriers, specific psychological factors, and media influence.

In summary, the interrelationships between risk factors for pilot murder-suicide form a complex, self-reinforcing system driven by psychological, occupational, and systemic stressors; see Fig. 2. At its core, psychological distress (e.g., depression, suicidal ideation) interacts bidirectionally with occupational stressors like fatigue, performance pressure, and isolation, creating a vicious cycle where each exacerbates the other. Stigma and regulatory barriers further amplify risk by discouraging pilots from seeking help, leading to underreporting and delayed intervention. This secrecy is compounded by cultural norms that glorify resilience over vulnerability, while media contagion–through sensationalized coverage of incidents–can normalize or even glamorize such acts, increasing the likelihood of copycat behavior. Access to means (e.g., aircraft) lowers the threshold for acting on suicidal impulses, particularly during crises. These factors are interconnected through three reinforcing loops: (1) psychological and occupational stress feeding off each other, (2) stigma perpetuating underreporting and delayed support, and (3) media coverage amplifying risk. Breaking these loops requires systemic changes: destigmatizing mental health care, reforming regulatory policies, fostering supportive cultural norms, and promoting responsible media reporting.

3.3. Education / training

Education and training are essential in preparing aviation personnel to manage mental health challenges effectively. A comprehensive approach that integrates mental health awareness, psychological screening, and continuous support can significantly enhance aviation safety. An empirically derived taxonomy for classifying pilot violations, including extreme behaviors like pilot suicides, underscores the importance of understanding and addressing the underlying motivations behind such actions (English and Branaghan, 2012). This knowledge can inform targeted training and education changes, focusing on proactive safety management and fostering a just culture. Training programs should integrate balanced regulations and flight deck design considerations to enhance overall safety management and policy-making in aviation. Training programs should focus on reducing stigma and providing targeted support for subpopulations at higher risk (Wu et al., 2016). Semi-structured diagnostic interviews can capture a broader range of psychological disorders, highlighting the need for improved mental health support and education (Ackland et al., 2023). Training should also emphasize the importance of regular psychological evaluations and resources for mental health support targeted at younger pilots (Politano and Walton, 2016). Proactive mental health management and enhanced screening and monitoring are essential. Proactive risk management strategies, including the use of leading indicators and smart technologies, can be integrated into educational curricula to better prepare pilots for managing their mental health (Cahill et al., 2020). Digital self-management tools for pilots can empower them to monitor and manage their well-being, mitigating the risk of suicidal ideation (Cahill et al., 2020). Integrating biofeedback techniques like the Quick Coherence Technique (QCT) into training programs can help pilots enhance their psychophysiological resilience (Li et al., 2023). Specialized training programs for aeromedical examiners and the integration of advanced neurocognitive testing tools can contribute to improved training and education changes in the context of pilot suicides (Vuorio et al., 2024). Overall, the FAA and industry stakeholders have expanded mental health training for aviation medical examiners and encouraged peer support programs. The major goal of training initiatives is to teach pilots and staff to recognize warning signs and respond effectively, fostering a culture of vigilance and support.

3.4. Vigilance / monitoring

Robust monitoring systems are essential for promptly identifying and managing mental health concerns among pilots. Enhanced vigilance during high-risk periods, particularly those following highly publicized incidents, is crucial in preempting potential crises (Rice et al., 2015; Winter and Rice, 2015). By doing so, vigilance and monitoring can help reduce the risk of pilot suicides through early detection and timely intervention, thereby preventing the escalation of mental health issues. However, it remains uncertain whether existing technological tools are sufficiently advanced–or ethically appropriate–to reliably detect psychological crises without undermining privacy and trust.

Anonymous, web-based surveys have helped reduce underreporting and reveal the true prevalence of issues such as depression and suicidal thoughts among pilots, underscoring the need for proactive organizational support (Ackland et al., 2022; Gambetta, 2005; Pasha et al., 2018; Schmid et al., 2018; Wu et al., 2016). A structured approach to prevention should balance medical privacy with public safety while promoting pilot support programs for early intervention (Schmid et al., 2018). Recognizing that pilots across different sectors share similar mental health risk profiles suggests that monitoring and vigilance strategies can be adapted across pilot groups to promote more consistent and effective support (Otto and Webber, 2013). More frequent and comprehensive mental health screenings, along with longitudinal research, can help understand and address long-term mental health impacts on pilots, further enhancing flight safety. A comprehensive framework linking work-related stress to severe mental health issues provides unique insights into specific impact scenarios (Cahill et al., 2020). This framework can enhance monitoring and vigilance for early detection and prevention of critical incidents.

Proactive approaches to wellbeing management, integrating digital self-management tools, and emphasizing organizational support and regulatory changes can mitigate these risks. In the context of single-pilot operations, ground-based support or onboard autonomy could serve as additional safety measures to intervene in critical situations (Harris, 2023). Overall, regular mental health assessments, fatigue management systems, and supportive work environments are essential for enhancing monitoring and vigilance regarding pilot suicides (Aljurf et al., 2018), especially while integrating multiple data sources for more accurate mental health assessments can help in early identification and intervention for pilots at risk (Ackland et al., 2023; Mulder and Rooy, 2018).

Airlines are actively exploring and implementing technologies to monitor pilot mental health and fatigue, though widespread, standardized adoption remains limited. AI-based face and voice analysis systems, such as those developed by Blueskeye AI[5], are being trialed to detect fatigue, stress, and anxiety by analyzing behavioral and physiological signals in real time[6]. Wearable devices, including smartwatches and ECG patches, are also under investigation for tracking physiological indicators like heart rate variability and sleep quality, but their use is not yet mandatory due to privacy and validation concerns (Yuan et al., 2025). AI-powered psychological assessment tools are emerging to analyze speech patterns and behavioral data, supporting mental health programs but not yet integrated into standard operations[7].

3.5. Enhanced mental health support

Proactive mental health resources and early intervention programs are crucial, including peer-support programs foster a supportive organizational culture, ensuring that pilots have access to the necessary support systems. Airlines can provide proactive mental health support, such as cognitive behavioral therapy and internet-based treatments (Wu et al., 2016). Implementing standardized psychological tests and offering ongoing mental health support programs can help identify and address mental health issues early on (Bor et al., 2019). Airlines can adopt comprehensive diagnostic tools, such as the structured interviews, to accurately assess pilots' mental health and target specific vulnerability and protective factors (Ackland et al., 2023). Creating a supportive and communicative organizational culture is essential for mitigating pilot suicides. Airlines can foster an environment that alleviates stress and encourages help-seeking behavior among pilots (Gambetta, 2005). Additionally, airlines can implement crisis intervention and emergency response protocols to manage mental health concerns effectively (Vuorio and Bor, 2020). Addressing specific work-related stressors, such as fatigue and social isolation, is also vital. Airlines can target support systems to manage daily stressors and provide proactive well-being strategies and stigma reduction (Cahill et al., 2018). Encouraging adequate recovery and training programs to address the dangers of presenteeism can further mitigate risks associated with pilot suicides (Harris, 2023; Johansson and Melin, 2018). Providing high-quality, structured, and comprehensible psychological reports can significantly influence a pilot's career and the safety of air

[5] https://www.blueskeye.com/
[6] https://schaeffler-tomorrow.com/en/article/ai-in-the-cockpit
[7] https://www.aerosociety.com/news/pilot-mental-health-can-ai-powered-psychological-assessment-help/

travel (Morse and Bor, 2016). Enhanced medical training, stricter certification processes, and collaborative efforts among specialists can also address pilot mental health more effectively (Vuorio et al., 2015). Moreover, a structured notification process ensures timely and accurate reporting of mental health concerns, enabling better support and prevention strategies (Vuorio and Bor, 2021).

3.6. Normalizing health problems / reducing stigma

Normalizing mental health discourse within the aviation industry is essential for reducing stigma and encouraging open discussions about mental health issues. The existing stigma can create a barrier to seeking help, leading to underreporting of mental health struggles and increasing the risk of tragic events. Several studies have contributed novel insights into how addressing and reducing this stigma can enhance aviation safety. One significant aspect highlighted is the need for transparent communication and public education to address stigma and promote acceptance of mental health treatments among pilots (Winter et al., 2017). Public perceptions of pilots taking antidepressants, for instance, shifted temporarily after the 2015 Germanwings accident, indicating that open dialogue and education can influence attitudes towards mental health in the aviation industry. Another key finding is the importance of anonymous assessments and proactive mental health support tailored to the aviation context (Cahill et al., 2020; Pasha et al., 2018; Wu et al., 2016). These measures can help identify and address mental health issues without the fear of career repercussions, thereby normalizing mental health treatment. Additionally, the implementation of peer support programs and emotional management strategies has been shown to reduce stigma by fostering a culture of openness and support within the high-stress aviation industry (Bor et al., 2017; Cahill et al., 2018; Knoll, 2016; Mulder and Rooy, 2018). By focusing on real-time assessments of cognitive skills rather than clinical diagnoses, this method allows pilots to continue flying if their performance measures are within accepted ranges, thereby normalizing the presence of mental health issues. This approach encourages pilots to seek mental health care without fear of immediate loss of flying status, leading to earlier interventions and better overall mental health management. Addressing the stigma also involves creating a supportive and non-stigmatizing workplace culture within the aviation industry (Bor et al., 2002; Knoll, 2016; Rice et al., 2015; Stewart and Harris, 2019).

3.7. Technological solutions

Innovations such as ground-based support systems, onboard autonomy, and real-time monitoring are instrumental in intervening potential crisis scenarios. Moreover, the development of sophisticated analytical techniques for health monitoring and risk assessment is critical for proactive mental health management, particularly supported by Artificial Intelligence (AI). One of the primary contributions of AI is in the continuous monitoring of pilots' mental and physical health. Wearable devices equipped with advanced sensors can track biological metrics such as heart rate, sleep patterns, and stress levels in real-time. This data can be analyzed using AI algorithms to detect early signs of mental distress, allowing for timely intervention and support (Foont, 2007). For instance, the Inner Balance device can provide real-time feedback on psychophysiological coherence, which can be integrated into pilot training programs to monitor and enhance resilience (Li et al., 2023). Additionally, AI-driven sentiment analysis tools can monitor public emotions and perceptions about pilots' mental health, enabling proactive crisis management and the development of culturally sensitive training programs (Winter and Rice, 2015). These technologies not only improve safety but also help in reducing the stigma associated with mental health issues by providing discreet and accessible support services. Furthermore, AI can play a crucial role in the development of advanced psychological screening tools and behavioral analytics to identify early signs of distress in pilots. Machine learning algorithms can analyze vast amounts of data to create risk assessment frameworks that identify high-risk individuals, driving the creation of new technologies for real-time monitoring and intervention (?). For example, the Psychosocial Reconstruction Inventory (PRI) enhances traditional aviation accident investigations by providing deeper insights into the psychological and social factors behind pilot error, particularly in cases of pilot suicides (Yanowitch et al., 1972). This leads to the development of targeted support systems for at-risk pilots, further reducing the stigma and encouraging open communication about mental health challenges. Additionally, AI can facilitate the integration of psychological autopsies into accident investigations, providing a more comprehensive understanding of the factors contributing to pilot suicides (Vuorio et al., 2014a). This approach can lead to the development of more advanced statistical models to identify suicidal incidents accurately, despite the current limitations of high false-positive rates (Politano and Walton, 2016). In the realm of single-pilot or remotely operated aircraft, technology plays a vital role in enhancing safety and mitigating risks associated with pilot suicides. Ground-based support or onboard autonomy can intervene in potential pilot suicide and murder-suicide incidents, adding extra layers of safety (Harris, 2023). Advanced automation and redundancy systems can manage pilot workload and ensure safety, particularly in cases of sudden pilot incapacitation (Somerville et al., 2023). Overall, trust in automation, data security, and regulatory changes are essential to facilitate the safe adoption of these technologies in commercial aviation. By leveraging real-time monitoring, advanced screening tools, and innovative support systems, the aviation industry can create a safer and more supportive environment for pilots, ultimately enhancing overall aviation safety.

While these technological innovations hold substantial promise for preemptive mental health intervention, they also introduce significant challenges regarding the scope of surveillance and the protection of sensitive personal data. Wearable devices equipped with advanced sensors enable the collection of granular biometric data, including heart rate variability, sleep quality, and stress markers, which AI algorithms analyze to detect early signs of cognitive or emotional distress. The pervasive nature of such monitoring, however, raises critical questions about the boundaries of workplace surveillance and the potential for unintended consequences, such as the erosion of pilot trust or the exacerbation of occupational stress due to perceived invasiveness. Central to these concerns is the tension between the imperative for safety and the preservation of individual privacy. Pilots, as highly trained professionals, may view continuous health monitoring as an encroachment on their autonomy, particularly if data collection protocols lack transparency or if the use of their health information is not explicitly consensual. The ethical deployment of these systems necessitates robust frameworks for informed consent, data encryption, and access control to mitigate risks of unauthorized disclosure or misuse. To address these challenges, the aviation industry must adopt an approach that prioritizes both safety and ethical integrity. This includes establishing clear regulatory guidelines, fostering pilot participation in the design and implementation of monitoring systems, and ensuring that data-driven interventions are accompanied by safeguards against stigmatization.

Finally, it should be noted how crew scheduling systems (Bövarsdóttir and Stidsen, 2025; Kasirzadeh et al., 2017; Sun et al., 2026; Wen et al., 2021), while predominantly designed to optimize operational efficiency, cost-effectiveness, and sustainability aspects (Wang et al., 2025; Wen et al., 2022, 2024, 2020), may significantly impact pilots' mental health and even contribute to suicidal ideation. Irregular, unpredictable schedules - often characterized by frequent time zone changes, long duty periods, and insufficient rest - disrupt circadian rhythms, leading to chronic fatigue and sleep deprivation. These physiological stressors amplify psychological strain, increasing the risk of anxiety, depression, and burnout. The pressure to maintain peak performance under such conditions can foster feelings of isolation, helplessness, and professional dissatisfaction, especially when pilots perceive their well-being as secondary to corporate priorities. Prolonged exposure to these stressors can erode resilience, making pilots more vulnerable to severe mental health crises, including suicidal thoughts. Crew scheduling algorithms could more prominently prioritize human factors - such as adequate rest, social support, and mental health resources.

4. Discussion

The mitigation of pilot murder-suicides represents a pressing challenge for the aviation industry. Emerging research underscores the imperative for aviation authorities, airlines, and industry stakeholders to adopt novel managerial strategies that synthesize regulatory oversight, risk assessment, technological innovation, and organizational culture. Central to this endeavor is the reformulation of policy frameworks to prioritize both public safety and pilot well-being through transparent reporting mechanisms, standardized investigative protocols, and cross-border regulatory harmonization. Unlike conventional safety measures, which often focus on technical failures, addressing pilot murder-suicides requires a systemic lens that accounts for the dynamic interplay of psychological, occupational, and organizational factors. For instance, the 2025 Mental Health in Aviation Act in the U.S. exemplifies a paradigm shift toward non-punitive, support-oriented policies, emphasizing confidential mental health services and stigma reduction campaigns. Such initiatives, when coupled with interdisciplinary post-incident analyses–including psychological autopsies–can yield actionable insights for proactive risk management and evidence-based policymaking.

A critical managerial insight lies in the identification and mitigation of multifaceted risk factors, which extend beyond individual psychological vulnerabilities to encompass systemic stressors such as fatigue, circadian disruption, and organizational culture. Recent studies reveal that up to 12.6% of pilots experience depression, with 4.1% reporting suicidal ideation–figures exacerbated by occupational demands and regulatory pressures. To address these challenges, airlines must implement data-driven risk assessment frameworks that integrate anonymous surveys, real-time monitoring, and longitudinal research. For example, AI-powered behavioral analytics and wearable biometric sensors offer unprecedented opportunities for early detection of distress, yet their deployment must be ethically calibrated to avoid infringing on pilot autonomy. Additionally, media contagion–where sensationalized reporting amplifies stigma and copycat risks–demands collaborative strategies between aviation authorities and media outlets to promote responsible communication that balances transparency with harm reduction.

The operationalization of these insights hinges on three managerial pillars: education, vigilance, and support. First, mental health literacy must be embedded into pilot training curricula, with an emphasis on destigmatization, peer support networks, and digital self-management tools (e.g., biofeedback applications). Second, real-time vigilance systems, such as AI-driven fatigue detection and anonymous reporting platforms, enable proactive intervention while preserving confidentiality. Third, enhanced mental health support–ranging from cognitive behavioral therapy (CBT) to crisis intervention protocols–must be accessible, non-punitive, and culturally attuned to the high-stress aviation environment. A groundbreaking approach in this domain is the integration of ground-based support systems for single-pilot operations, which can preemptively intervene in potential crisis scenarios through autonomous onboard systems and real-time data analytics.

Ultimately, the sustainable prevention of pilot murder-suicides requires a paradigm shift from reactive safety measures to a proactive, systems-thinking model that aligns technological innovation, regulatory reform, and organizational culture. By adopting cross-disciplinary collaboration, leveraging emerging technologies, and fostering a culture of psychological safety, the aviation industry can redefine its approach to mental health–transforming it from a taboo topic into a cornerstone of operational resilience. The managerial implications of this shift are profound: it not only enhances aviation safety but also strengthens pilot trust, organizational reputation, and public confidence in air travel. Future research should focus on longitudinal evaluations of these strategies to refine their efficacy and ensure their scalability across global aviation networks.

Future work should prioritize harmonized, non-punitive policies that increase disclosure without eroding safety; multi-level risk models that improve predictive value without intolerable false positives; and training that changes observable behaviors (help-seeking, peer referral) rather than attitudes alone. Vigilance and monitoring need rigorous field evaluation, clear governance, and privacy-preserving analytics to avoid mission creep. Enhanced mental health support should be tested for dose-response benefits and tailored across airline types and pilot populations. Media guidance that minimizes contagion while preserving transparency remains an underdeveloped lever. Technological measures can contribute but are not a panacea. The most promising directions are low-intrusion tools that add incremental value beyond self-report and peer observation, coupled with engineering and procedural barriers that raise the threshold for harmful acts without creating new hazards. Overall, the evidence favors layered defenses–supportive human systems plus targeted technical and operational controls–coordinated across borders and assessed with transparent, reproducible methods.

5. Conclusions and future research questions

Pilot-perpetrated murder-suicides are exceedingly rare yet system-shaping. Synthesizing the literature within our PREVENT framework shows that prevention cannot rest on screening alone: risk emerges from the interaction of individual vulnerabilities with organizational, operational, regulatory, and sociocultural determinants. The most defensible approach is multi-level–combining clinical pathways and peer support, just-culture reporting and fitness-for-duty governance, and design/operational barriers–implemented with strong privacy safeguards and evaluated for real-world impact. Across cases, several patterns recur. Attribution of intent is frequently disputed or left undetermined, indicating the need for transparent, convergent evidence standards (including psychological-autopsy methods) and caution against post hoc inference. Opportunity structures matter: cockpit-access rules, single-pilot moments, and transitions such as return-to-work or recent recertification repeatedly appear as critical junctures. Stigma and regulatory chilling effects deter disclosure and help-seeking; where non-punitive, confidential support is available, reporting improves. Stressors often cluster–fatigue and circadian disruption alongside financial, legal, relationship, or occupational pressures–while intense media coverage risks contagion through sensational framing.

CRediT authorship contribution statement

Sebastian Wandelt: Writing – review & editing, Writing – original draft; **Yurou Zhang:** Writing – review & editing, Writing – original draft; **Oscar Oviedo-Trespalacios:** Writing – review & editing, Writing – original draft; **Xiaoqian Sun:** Writing – review & editing, Writing – original draft.

Data availability

No data was used for the research described in the article.

Acknowledgments

This study is supported by the National Natural Science Foundation of China (Grant No. U2233214).

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