Langit Biru: Jurnal Ilmiah Aviasi Vol. 19 No. 1 February 2026 Page. 01 : 09
ISSN (p) 1979-1534 ISSN (e) 2745-8695

PILOT SHORTAGE AND TECHNICIAN FATIGUE: SAFETY RISK ANALYSIS AND POLICY IMPLICATIONS FOR INDONESIA'S POST-PANDEMIC AVIATION INDUSTRY

Wisnu Darjono TU.[(1)], Farah Khalda Arinta[(2)*], Fachri Muhammad Rasyid[(3)]
[1]Centre for Strategic and Aviation Studies (CSAS), Indonesia
[2]Bandara Budiarto, Curug_Ditjen Perhubungan Udara_Kemenhub, Indonesia
[3]Urban and Regional Planning, Institut Teknologi Sumatera (ITERA), Indonesia

Email: [1]wdtu1956@gmail.com; [2]farahkhalda81@gmail.com; [3]fachrimuhammad148@gmail.com
Corresponding author: farahkhalda81@gmail.com

Received:	Revised:	Accepted:
27 September 2025	15 December 2025	02 February 2026

Abstract: In the post-COVID-19 era, Indonesia's aviation industry faces two major human resource challenges: pilot shortages and technician fatigue. High costs of type rating have left many pilot graduates unemployed despite strong airline demand, while long working hours increase maintenance fatigue risks that threaten flight safety. This study aims to analyse the safety risks arising from pilot shortages and technician fatigue in Indonesia's post-pandemic aviation industry and to identify relevant policy implications from a human factors perspective. This study applies a qualitative descriptive approach, drawing on secondary data from official reports, academic publications, and aviation regulations, complemented by brief stakeholder interviews. While previous studies generally address pilot shortages and technician fatigue separately, this research integrates both issues within the Indonesian post-pandemic context. The findings reveal strong links between structural barriers, such as high training and certification costs, and operational risks, such as fatigue, which together create a significant aviation safety gap. Policy recommendations include expanding access to type rating programs, enforcing Fatigue Risk Management Systems (FRMS), and strengthening technician certification standards. This integrative analysis contributes a novel perspective to aviation safety literature and offers actionable strategies to support Indonesia's post-pandemic aviation recovery.

Keywords: aviation safety, human factors, fatigue risk management, pilot shortage, technician fatigue

Introduction

The aviation industry is a strategic sector that supports human mobility, logistics distribution, and global connectivity. Its sustainability, however, relies heavily on the availability of qualified human resources, particularly pilots and aircraft maintenance technicians (Dube, 2022; Garcia et al., 2018; ICAO, 2022; National Research Council 2002; Shanmugam & Paul Robert, 2015; Tiftik & Yakupoğlu, 2023). In the post-COVID-19 era, both the global and Indonesian aviation industries face a severe human resource crisis, especially the shortage of pilots and the rising risk of technician fatigue (Adrienne et al., 2020; Cao et al., 2024; Mizzi et al., 2024; Stolzer et al., 2023). As noted in field reports, "behind the cockpit, the human resource crisis threatens aviation safety" (Darjono, 2025; Darjono et al., 2025). This crisis did not emerge suddenly but was rooted in operational downsizing, layoffs, and suspended training programs during the pandemic, while the recovery of flight demand has not been matched by sufficient numbers of trained personnel.

DOI: https://doi.org/10.54147/langitbiru.v19i01

Industry projections further confirm the urgency. Boeing forecasts that the Asia-Pacific region will require hundreds of thousands of new personnel in the next two decades, including approximately 248,000 pilots and 268,000 technicians by 2035 (Boeing, 2023). In the United States, demand for 127,000 new pilots is expected between 2023 and 2042 (Erenay et al., 2024). These projections highlight the acute human resource needs in both Indonesia and globally (Adanov et al., 2020; Cahyadi et al., 2022; Demirok et al., 2025; Dinçer & Yirmibeşoğlu, 2024; Keller et al., 2020; Supardam et al., 2025). Training costs exacerbate the challenge, as type-rating transitions directly increase expenses, while global industry trends indicate rising professional training fees (Cao et al., 2024; Valenta, 2018).

Internally, Indonesian technicians are also confronted with fatigue-related challenges. A study of maintenance, repair, and overhaul (MRO) companies revealed that even with a new 7-hour shift system, 26% of technicians still reported fatigue and difficulty concentrating, particularly during the fifth consecutive night shift (da Silva et al., 2024a; da Silva et al., 2024b; Li & He, 2024). Further, research at Gadjah Mada University (UGM) found that work–life imbalance accounted for 56.5% of workplace stress among technicians (Pradana et al., 2023)**.**

These conditions underscore that Indonesia's post-pandemic human resource problems involve not only quantity but also quality and sustainability. A comprehensive policy approach, grounded in human factors, is essential for ensuring a safe and sustainable recovery of the national aviation industry.

Ironically, in Indonesia, "*hundreds of fresh graduate pilots remain unemployed because they cannot afford type rating costs, which may reach IDR 1.2 billion*" (Darjono, 2025). A type rating is a prerequisite for operating specific aircraft types used by airlines. At the same time, technicians work under intense pressure and tight maintenance deadlines. This combination, coupled with extended work hours, increases fatigue risks (ICAO, 2022). Reports note that "*around 20% of aircraft accidents in the United States between 1990 and 2020 were linked to technician errors caused by fatigue*" (Darjono, 2025).

These findings confirm that pilot shortages and technician fatigue are not merely employment issues but fundamental aviation safety concerns (Caldwell, 2005; Lee & Kim, 2018; Li & He, 2024; Miller et al., 2023; Nunes & Cabon, 2015; Olaganathan et al., 2021). Pilot shortages may disrupt operational balance, resulting in inefficient flight schedules and increased workload for available pilots, while technician fatigue may compromise maintenance quality and elevate the risk of technical failures. This aligns with the principles of human factors in aviation safety, where human limitations are key determinants of accident risk. Against this background, this study analyzes post-pandemic human resource challenges in Indonesia's aviation sector, focusing on two central issues: pilot availability and technician fatigue. It further aims to formulate policy recommendations and mitigation strategies to strengthen national aviation safety and resilience.

In modern aviation safety systems, human factors remain a crucial element despite continuous technological advancements. Aviation safety depends not only on technical aspects such as aircraft condition or weather, but also on the physical, mental, and professional competence of aviation personnel (Cahill et al., 2020; Cheng & Shyur, 2025; Stolzer et al., 2023; Vural, 2023). Scholars emphasize that more than 70% of global aviation incidents in the last decade involved human factors (Hobbs, 2008; Shappell et al., 2017), both in the cockpit and in aircraft maintenance. A recent bibliometric analysis also reported a surge in aviation-related human factors publications in 2023, reflecting growing academic attention to this issue (Tuncal & Altıntaş, 2025).

Since the COVID-19 pandemic, the pilot shortage has emerged as a global phenomenon. The recovery of air traffic demand has not been matched by a sufficient supply of qualified pilots (ICAO, 2022). Boeing's *Pilot and Technician Outlook 2023–2042* projects the need for approximately 649,000 new pilots worldwide, with the Asia–Pacific region as the region with the highest demand. In Indonesia,

the high cost of additional training, such as type rating, approximately IDR 1.2 billion, creates a significant barrier for aviation school graduates seeking immediate industry entry (Darjono, 2025).

Fatigue is another critical issue, affecting not only pilots but also technicians. The Federal Aviation Administration (FAA, 2022) notes that fatigue impairs concentration, decision-making, and motor coordination among aircraft technicians. It further reports that technicians working more than 12 hours per shift face a 2.5 times higher risk of errors. The National Transportation Safety Board (NTSB) documented that around 20% of U.S. aviation accidents between 1990 and 2020 were directly linked to technician errors caused by fatigue (da Silva et al., 2024a).

International literature continues to expand the empirical evidence on fatigue and operational risk. Sieberichs, Corrigan, and McDonald analyzed over 16,000 safety reports and found that fatigue-related events were more frequently reported anonymously, with contributing factors such as inadequate rest and poor hotel environments (Sieberichs et al., 2024). A study in *Safety Science* (2024) revealed that 52.9% of aircraft maintenance technicians experienced fatigue, which correlated positively with drowsiness and workload, while also reducing quality of life. Current regulations, however, remain focused primarily on flight crews and insufficiently address technicians (da Silva et al., 2024a). Similarly, research in the *International Journal of Aviation, Aeronautics, and Aerospace* reported that aviation maintenance students often experience fatigue, despite being aware of its risks for safety (Zimmermann et al., 2022).

A number of aviation authorities have begun strengthening regulations related to fatigue risk management. The FAA encourages the integration of Fatigue Risk Management Systems (FRMS) within the broader Safety Management System (SMS) (FAA, 2022). Indonesia's Directorate General of Civil Aviation (DGCA) has issued a draft FRMS guideline (2025) adopting a SMART approach, specific, measurable, achievable, realistic, and time-bound, as a complement to existing Flight Duty Time Limitation (FDTL) procedures (DGCA, 2025). Meanwhile, the European Cockpit Association (ECA) reported that three out of four pilots had experienced microsleep episodes in the four weeks leading up to peak season, highlighting the high level of fatigue among European pilots (Association, 2023).

From this body of evidence, it is clear that aviation safety cannot be separated from the interplay of human factors, pilot shortage, and fatigue. However, the literature has yet to thoroughly explore the interconnection of these aspects, particularly within Indonesia or other developing countries. This underscores the importance of studies that integrate these dimensions to inform effective and context-specific aviation safety policies and strategies.

Methods

This study employs a qualitative approach (Creswell & Plano Clark, 2023; Creswell & Poth, 2016; Moleong, 2017; Subrahmanyam, 2025; Sugiyono, 2014) with a descriptive analysis method to examine the shortage of pilots and the risk of aircraft technician fatigue in Indonesia's post-COVID-19 context. This approach was chosen because it enables the researcher to gain an in-depth understanding of the relationship between human resource factors and aviation safety by relying on the interpretation of narrative and contextual data.

The data were drawn from two main sources: secondary and primary. Secondary sources included official reports from international and national aviation organizations such as *Boeing Pilot and Technician Outlook* (2023), *Global Aviation Safety Plan* (ICAO, 2022), and *Fatigue Risk Management Systems* (FAA, 2022). Recent academic publications on human factors and aviation safety, such as those by da Silva and others, also provided key references. In addition, the *Civil Aviation Safety Regulation* (CASR) was used to understand the national regulatory framework. Primary data were obtained through brief interviews with pilot instructors, aircraft technicians, and regulatory officials, which offered direct insights into field conditions.

Data collection was conducted through document analysis, interviews, and the review of news reports and popular articles, including coverage from *Kompasiana* that provided field perspectives and public opinion (Darjono, 2025). Data were analyzed using content analysis through thematic coding to identify key issues such as pilot shortage, type rating barriers, technician fatigue, and aviation safety implications. Triangulation was employed by comparing data from multiple sources to ensure validity, while comparative analysis was used to assess the similarities and differences between conditions in Indonesia and global trends reported by ICAO, Boeing, and FAA.

This study is limited to the post-pandemic period (2022–2024) and does not include a detailed quantitative analysis of aviation accident or incident data. Nevertheless, the findings are expected to serve as a foundation for policy recommendations and mitigation strategies for the government, airlines, and aviation training institutions in ensuring the sustainability of a reliable human resource base in Indonesia's aviation industry.

Discussion

1. The Gap Between Pilot Demand and Availability

The analysis of data indicates that in the post-COVID-19 period, the demand for pilots in Indonesia has risen sharply alongside the recovery of the aviation industry. Boeing's *Pilot and Technician Outlook 2023–2042* projects the need for approximately 649,000 new pilots globally, with the Asia–Pacific region accounting for 41% of total demand. This projection places Indonesia in a critical position, as it is one of the largest aviation markets in Southeast Asia (Boeing, 2023). The trend highlights a serious challenge for Indonesia in bridging the gap between industry needs and the availability of qualified human resources.

Paradoxically, field observations reveal that hundreds of flight school graduates remain unemployed because they cannot afford the type rating, which costs around IDR 1.2 billion (Darjono, 2025). Interviews with representatives of pilot training schools revealed that, on average, only 60–80 graduates per year are administratively eligible, yet not all are absorbed by airlines due to the absence of a type rating. One graduate noted:

> *"I graduated in 2022, but I still haven't flown because I cannot take the type rating. The cost is too high, reaching up to 1.2 billion rupiah."* (Interview, March 2025)

This situation indicates a bottleneck between basic pilot training and initial operational readiness, which ideally should be supported by affordable advanced training systems. Without systemic interventions such as subsidies or innovative financing schemes, graduates will continue to accumulate while airlines remain short of cockpit crews.

The problem is compounded by the limited number of national airlines offering scholarships or bonding systems for prospective pilots. Such economic pressures not only create recruitment bottlenecks but also extend the "time to cockpit" for new graduates (Siebericchs et al., 2024). However, the reality on the ground reveals a paradox: hundreds of flight school graduates are unemployed because they cannot afford the high cost of a type rating (Darjono, 2025). This situation demonstrates a structural gap between the number of graduates and the number of pilots ready for operations. In contrast, countries such as Malaysia and Vietnam have successfully reduced this bottleneck through Cadet Pilot Sponsorship Programs run by major airlines, while Indonesia still lacks similar incentives (Valenta, 2018).

This structural gap has long-term implications. Although Indonesia has one of the fastest-growing aviation markets, the shortage of ready-to-fly pilots hampers the expansion of domestic airlines. Recent bibliometric studies also confirm that research on pilot shortage has increased significantly in the post-pandemic period, reflecting its growing status as a global research agenda (Tuncal & Altıntaş,

2025). The prolonged time-to-cockpit for graduates risks slowing the expansion of domestic airlines, with some Southeast Asian carriers reportedly delaying the opening of new routes due to a lack of qualified pilots.

2. Risks of Technician Fatigue in Aircraft Maintenance

Aircraft maintenance technicians represent the final line of defense in ensuring the airworthiness of an aircraft. This vital role requires precision, high concentration, and accuracy in every maintenance procedure. In reality, however, technicians often work under intense pressure due to tight maintenance schedules, short turnaround targets, and the limited number of certified personnel. These factors directly contribute to increased fatigue risks. Field data and interviews with technicians further reveal that heavy workloads, extended shifts, and the pressure to meet on-time performance targets exacerbate fatigue. One technician at a national airline noted:

> *"We often have to work 12 hours or more. If there is an AOG (Aircraft on Ground), we may be kept until late at night, and sometimes we have to return the next morning."*
> (Interview, February 2025)

According to the Federal Aviation Administration (FAA, 2022), technician fatigue reduces alertness, slows decision-making, and increases the likelihood of critical errors. Research by Silva and Santos reinforces this finding, showing that technicians working more than 12 hours per shift are 2.5 times more likely to make mistakes compared to those working within regulatory limits (da Silva et al., 2024a; da Silva et al., 2024b). International evidence is consistent: in the United States, around 20% of aviation accidents between 1990 and 2020 were directly linked to technician fatigue-related errors. This underscores that fatigue is not merely a workforce health issue but a serious aviation safety concern.

The Indonesian context presents additional complexities. The shortage of certified technicians compels operators to overutilize existing personnel, making long working hours difficult to avoid. A recent study in *Safety Science* found that 52.9% of aircraft maintenance technicians suffer from chronic fatigue, which significantly affects quality of life, work motivation, and technical error rates (da Silva et al., 2024a). Similar findings at Gadjah Mada University (Pradana et al., 2023) revealed that work–life imbalance is a major contributor to technician stress, which in turn worsens fatigue conditions.

The implications of this phenomenon are critical. Technician fatigue can result in maintenance errors that remain undetected until the aircraft is back in operation, thereby creating potential safety risks. Consequently, fatigue risk management, through the implementation of Fatigue Risk Management Systems (FRMS), stricter supervision of work-hour regulations, and the expansion of certified technician numbers, has become an urgent necessity to ensure the sustainability of aviation safety standards in Indonesia.

3. Implications for Aviation Safety

The combination of pilot shortages and technician fatigue creates a dangerous safety gap. Pilot scarcity leads to tighter scheduling and reduced rest periods, particularly in low-cost carriers with high utilization rates. At the same time, technician errors caused by fatigue are not always detected during final inspections, posing risks of incidents once the aircraft is already airborne.

In Indonesia, the availability of detailed technical incident data in the public domain remains limited, a condition that is not unique and has also been observed in other aviation systems with confidential reporting mechanisms (ICAO, 2022; Stolzer et al., 2023). Previous studies in aviation safety have noted that operational pressures, such as schedule adherence and resource constraints, may

influence safety-related decision-making when organizational safety culture is insufficiently mature (Hobbs, 2008; Shappell et al., 2017).

In this context, insights from stakeholder interviews suggest that operational demands may at times challenge the consistent application of safety principles. As one regulatory official noted,

> *"Regulations under the CASR framework are sufficient, but their implementation still depends on the culture and commitment of airline management."*
> *(Interview, April 2025)*

This observation aligns with safety management system (SMS) theory, which emphasizes that effective safety performance depends not only on formal regulations but also on organizational culture, leadership commitment, and reporting practices.

Both pilot shortages and technician fatigue carry serious implications for aviation safety, as they are directly linked to human factors. From the pilot's perspective, workforce shortages push airlines to schedule tighter rosters to meet market demand, a condition that has been widely associated with reduced rest opportunities and increased fatigue risk (ICAO, 2022; Lee & Kim, 2018). Empirical evidence shows that insufficient rest periods significantly impair alertness and decision-making performance in flight operations (Caldwell, 2005). A survey by the European Cockpit Association revealed that three out of four European pilots experienced microsleep episodes in the four weeks leading up to peak season (Association, 2023). Although this survey was conducted in Europe, similar operational pressures related to pilot shortages and high aircraft utilization may potentially affect Indonesian pilots if shortages are not addressed promptly. Cockpit fatigue is especially dangerous, as it degrades concentration, situational awareness, and responses to emergencies.

On the other hand, fatigue among aircraft technicians creates equally serious risks, though often less visible. Fatigued technicians may commit maintenance errors that remain undetected until after the aircraft returns to operation, particularly in high-tempo maintenance environments with limited staffing (FAA, 2022; Hobbs, 2008). Studies have shown that fatigue-related maintenance errors are more likely to occur during extended shifts and night work, when vigilance and cognitive performance decline (da Silva et al., 2024c). Research by Siebericchs et al. found that fatigue-related technician reports were more frequently submitted through confidential reporting systems rather than official channels, suggesting significant underreporting in formal safety statistics (Siebericchs et al., 2024). Consequently, the actual safety risk associated with technician fatigue may be considerably higher than what is reflected in official incident data.

This phenomenon aligns with human factors theory, which identifies human error as a dominant contributor in more than 70% of global aviation incidents (Stolzer et al., 2023). The combination of pilot shortages, technician fatigue, and weak regulatory oversight of working hours creates a substantial safety gap. If left unaddressed, this gap could undermine the reliability of the national aviation system, threaten industry reputation, and produce broader socio-economic consequences. For these reasons, the issue warrants serious attention from regulators, airlines, and training institutions as part of a proactive safety strategy.

4. Mitigation Strategies

Addressing the complexity of pilot shortages and technician fatigue requires mitigation strategies that are comprehensive, collaborative, and grounded in human factors. These challenges cannot be resolved through fragmented policies; rather, they demand synergy among government, airlines, training institutions, and professional associations. One key priority is to expand access to type rating programs. The high cost, reaching approximately IDR 1.2 billion per pilot candidate (Darjono, 2025), creates a structural barrier that leaves many flight school graduates unemployed. The government could adopt cadet program models applied in several countries, where training costs are borne by airlines through bonding schemes, or implement public–private partnerships (PPP) involving

government subsidies. Such initiatives would not only reduce the financial burden on individuals but also ensure the steady supply of ready-to-fly pilots.

Fatigue risk management must also be strengthened through the consistent implementation of Fatigue Risk Management Systems (FRMS) across airlines and maintenance operators. The DGCA has proposed FRMS guidelines using the SMART approach, specific, measurable, achievable, realistic, and time-bound, which, if effectively enforced, could reduce chronic fatigue among both pilots and technicians (DGCA, 2025). These measures should be reinforced by strict oversight of duty hours and minimum rest periods, as recommended by the FAA and EASA, to mitigate the risks of overwork.

For technicians, strengthening training capacity through international certification is an urgent need. Collaborations with global institutions such as the EASA Training Academy or the FAA's Aircraft Maintenance Technician (AMT) certification program would enhance the competitiveness and competence of Indonesian technicians. With internationally recognized qualifications, technicians could not only meet domestic needs but also access global employment opportunities. If implemented in an integrated manner, these mitigation strategies would enable Indonesia not only to close the pilot shortage gap and reduce technician fatigue but also to strengthen the resilience of its aviation safety system and sustain industry growth in the post-pandemic era.

Conclusion

This study concludes that Indonesia's post-COVID-19 aviation sector faces a critical human resource, related safety gap driven by pilot shortages and technician fatigue. High costs and limited access to type rating programs constrain the availability of qualified pilots, while excessive workloads and extended duty hours increase fatigue among aircraft technicians, directly affecting maintenance quality and aviation safety. The novelty of this study lies in its integrated analysis of these two human factor issues within a single post-pandemic framework, demonstrating that structural training barriers and fatigue-related risk management challenges jointly undermine national aviation safety. To address this gap, the study recommends expanding access to type ratings through government support and airline–training partnerships, enforcing Fatigue Risk Management Systems (FRMS) in accordance with FAA and CASR standards, strengthening oversight of duty-hour and rest regulations, and enhancing technician training through internationally recognized certification. These policy measures are essential to reduce safety risks and support the long-term resilience of Indonesia's aviation industry.

Bibliography

Adanov, L., Efthymiou, M., & Macintyre, A. (2020). An Exploratory Study of Pilot Training and Recruitment in Europe. *International Journal of Aviation Science and Technology*, *1*(02), 44-51. https://doi.org/10.23890/IJAST.vm01is02.0201

Adrienne, N., Budd, L., & Ison, S. (2020). Grounded Aircraft: An Airfield Operations Perspective of the Challenges of Resuming Flights Post COVID. *Journal of Air Transport Management*, *89*, 101921. https://doi.org/10.1016/j.jairtraman.2020.101921

Association, E. C. (2023). Concerns of Fatigue and Related Hazards are Alarming for European Pilots. *Aero News Journal*. https://www.aeronewsjournal.com/2023/08/concerns-of-fatigue-and-related-hazards.html

Boeing. (2023). Boeing Releases 2023 Pilot and Technician Outlook. https://pathwaystoaviation.org/2023/08/01/boeing-releases-2023-pilot-and-technician-outlook/#:~:text=Boeing%20released%20its%20annual%20Pilot%20and%20Technician%20Outlook.,938%2C000%20cabin%20crewmembers%20over%20the%20next%2020%20years.

Cahill, J., Cullen, P., Anwer, S., Gaynor, K., & Wilson, S. (2020). The Requirements for New Tools for Use by Pilots and the Aviation Industry to Manage Risks Pertaining to Work-Related Stress

(WRS) and Wellbeing, and the Ensuing Impact on Performance and Safety. *Technologies*, *8*(3), 40. https://doi.org/10.3390/technologies8030040

Cahyadi, C. I., Oka, I. G. A. A. M., & Masito, F. (2022). The Importance of Aviation Vocational Education in Indonesia. *AL-ISHLAH: Jurnal Pendidikan*, *14*(2), 1869-1878. https://doi.org/10.35445/alishlah.v14i2.1257

Caldwell, J. A. (2005). Fatigue in Aviation. *Travel Medicine and Infectious Disease*, *3*(2), 85-96. https://doi.org/10.1016/j.tmaid.2004.07.008

Cao, K., Zhang, Y., & Feng, J. (2024). Prediction of Training Cost and Difficulty for Aircraft-Type Transition Based on Similarity Assessment. *Aerospace*, *11*(2), 166. https://doi.org/10.3390/aerospace11020166

Cheng, C.-B., & Shyur, H.-J. (2025). Introduction to Flight Safety. In *Flight Safety Management: Quantitative and AI Approaches* (pp. 1-17). Springer. https://doi.org/10.1007/978-981-96-1235-2_1

Creswell, J. W., & Plano Clark, V. (2023). Revisiting Mixed Methods Research Designs Twenty Years Later. *Handbook of Mixed Methods Research Designs*, *1*(1), 21-36. https://www.torrossa.com/en/resources/an/5730651#page=56

Creswell, J. W., & Poth, C. N. (2016). *Qualitative Inquiry and Research Design: Choosing among Five Approaches*. Sage publications.

da Silva, J. C., Barqueira, A., Magalhães, L. B., & Santos, L. F. (2024a). Human Fatigue in the Aircraft Maintenance Environment. *Safety Science*, *180*, 106634. https://doi.org/10.1016/j.ssci.2024.106634

da Silva, J. C., Barqueira, A., Magalhães, L. B., & Santos, L. F. (2024b). Insight into Human Fatigue: Statistical Analysis in Aircraft Maintenance. *ICASS-Congress_Italy*. https://www.icas.org/icas_archive/icas2024/data/papers/icas2024_0131_paper.pdf

da Silva, J. C., Barqueira, A., Magalhães, L. B., & Santos, L. F. (2024c). Insights into Human Fatigue: Statistical Analysis in Aircraft Maintenance. https://www.icas.org/icas_archive/icas2024/data/papers/icas2024_0131_paper.pdf

Darjono, W. (2025). Pilot Langka, Teknisi Lelah: Ancaman Nyata di Balik Layar Penerbangan. *Kompasiana*. https://www.kompasiana.com/wisnu22432/68817a7cc925c4079717ce92/pilot-langka-teknisi-lelah-ancaman-nyaya-di-balik-layar-penerbangan

Darjono, W., Arinta, F. K., Zalmansyah, A., Rasyid, F. M., & Aminah, S. (2025). Effectiveness of Airport Function Separation in Indonesia: A Case Study of Soekarno-Hatta and Halim Perdanakusuma Airports, with A Proposal for Utilizing Kertajati Airport for Private Aviation. *PLANNING MALAYSIA*, *23*. https://doi.org/https://doi.org/10.21837/pm.v23i39.1903

Demirok, A., Bagherpour, M., & Ulgen, S. (2025). Enhancing Human Resource Management in the Aviation Sector: A Comprehensive Analysis. Global Joint Conference on Industrial Engineering and Its Application Areas,

DGCA. (2025). Aviation Watchdog Issues Draft Guidelines for Fatigue Risk Management in Airlines.

Dinçer, F. C. Y., & Yirmibeşoğlu, G. (2024). Constraints on Women Pilots in Airline Industry: A Rising Sector of International Trade. *Journal of Air Transport Management*, *115*, 102538. https://doi.org/10.1016/j.jairtraman.2024.102538

Dube, K. (2022). Emerging from the COVID-19 Pandemic: Aviation Recovery, Challenges and Opportunities. *Aerospace*, *10*(1), 19. https://doi.org/10.3390/aerospace10010019

Erenay, B., Kibis, E., Cankaya, B., Cosgun, O., & Glassman, A. (2024). Navigating Airline Disruptions with Strategic Pilot Planning: An Optimization Approach for Long-Term Workforce Efficiency and Service Quality. *Journal of Marketing Analytics*, 1-17. https://doi.org/10.1057/s41270-024-00343-w

FAA. (2022). Fatigue Risk Management. https://www.faa.gov/about/initiatives/maintenance_hf/fatigue

Garcia, R. C., Pongkrapan, W., Sacares, R., & Surinta, N. (2018). Human Resource Availability Situation of Airline Companies in Thailand. *Available at SSRN 3308092*. https://dx.doi.org/10.2139/ssrn.3308092

Hobbs, A. (2008). An Overview of Human Factors in Aviation Maintenance. *ATSB Safty Report, Aviation Research and Analysis Report AR*, *55*(2008), 1-37. https://doi.org/http://www.dviaviation.com/files/45147577.pdf

ICAO. (2022). Annex 14 to the Convention on International Civil Aviation: Aerodromes (Vol. I, 8th ed.). *International Civil Aviation Organization, Montreal*, *13(03), 34-38*.

Keller, J., Mendonca, F., Cutter, J., Suckow, M., & Dillman, B. (2020). Justification and Development of Competencies to Transform a Collegiate Aviation Flight Program. *The Journal of Competency-Based Education*, *5*(3), e01216. https://doi.org/10.1002/cbe2.1216

Lee, S., & Kim, J. K. (2018). Factors Contributing to the Risk of Airline Pilot Fatigue. *Journal of Air Transport Management*, *67*, 197-207. https://doi.org/10.1016/j.jairtraman.2017.12.009

Li, Y., & He, J. (2024). A Review of Strategies to Detect Fatigue and Sleep Problems in Aviation: Insights from Artificial Intelligence. *Archives of Computational Methods in Engineering*, *31*(8), 4655-4672. https://doi.org/10.1007/s11831-024-10123-5

Miller, M., Mrusek, B., Herbic, J., & Garcia, P. A. A. (2023). Managing fatigue in aviation maintenance while promoting a human factors safety reporting system; a strategic approach to aviation safety. *Safety Management and Human Factors*, *105*(1), 54-63.

Mizzi, A., Lohmann, G., & Carim Junior, G. (2024). The Role of Self-Study in Addressing Competency Decline among Airline Pilots during the COVID-19 Pandemic. *Human factors*, *66*(3), 807-817. https://doi.org/10.1177/00187208221113614

Moleong, L. (2017). Metode Penelitian Kualitatif. *Remaja Rosdakarya Offset*, *cetakan ke-36*.

National Research Council , T. R. B. (2002). Future Flight: A Review of the Small Aircraft Transportation System Concept. *Committee for a Study of Public-Sector Requirements for a Small Aircraft Transportation System*.

Nunes, A., & Cabon, P. (2015). The Fatigue Conundrum: Whether It's Mild Sleepiness or Mind-Numbing Exhaustion, the Challenge of Fatigue on the Job can be Complex, Dangerous, and Surprisingly Difficult to Manage. *American Scientist*, *103*(3), 218-224.

Olaganathan, R., Holt, T. B., Luedtke, J., & Bowen, B. D. (2021). Fatigue and Its Management in the Aviation Industry, with Special Reference to Pilots. *Journal of Aviation Technology and Engineering*, *10*(1), 45. https://doi.org/10.7771/2159-6670.1208

Pradana, I. P. Y. B., Kumorotomo, W., & Susanto, E. (2023). The institutionalization of public innovation: Evidence from Indonesia. *Administration and Society*, *55*(4), 726-751. https://doi.org/10.1177/00953997231151438

Shanmugam, A., & Paul Robert, T. (2015). Human Factors Engineering in Aircraft Maintenance: A Review. *Journal of Quality in Maintenance Engineering*, *21*(4), 478-505. https://doi.org/10.1108/JQME-05-2013-0030

Shappell, S., Detwiler, C., Holcomb, K., Hackworth, C., Boquet, A., & Wiegmann, D. A. (2017). Human Error and Commercial Aviation Accidents: An Analysis Using the Human Factors Analysis and Classification System. In *Human error in aviation* (pp. 73-88). Routledge.

Siebericchs, S., Corrigan, S., & McDonald, N. (2024). How Pilot Fatigue Affects Operational Flight Risk in Scheduled Commercial Aviation. *Aviation Psychology and Applied Human Factors*. https://psycnet.apa.org/doi/10.1027/2192-0923/a000274

Stolzer, A. J., Sumwalt, R. L., & Goglia, J. J. (2023). *Safety Management Systems in Aviation*. CRC Press.

Subrahmanyam, S. (2025). The Importance of Qualitative Research in the Aviation Industry. In *Qualitative Research Methods in Air Transport Management* (pp. 1-26). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-7403-0.ch001

Sugiyono, P. (2014). Metode Penelitian Kombinasi (Mixed Methods). *Alfabeta, CV*, *12*.

Supardam, D., Surtiningtyas, S. R., Rifai, M., & Prayitno, H. (2025). Analysis of The Graduates' Requirement of Aviation Vocational Colleges in Indonesia. *Langit Biru: Jurnal Ilmiah Aviasi*, *18*(2), 66-79. https://doi.org/10.54147/langitbiru.v18i2.1276

Tiftik, C., & Yakupoğlu, E. (2023). The Importance of Aviation Safety in Terms of Human Resources Management in Air Cargo Transportation. *Uluslararası Sosyal Bilimler ve Eğitim Dergisi*, *5*(8), 125-146. https://dergipark.org.tr/en/pub/usbed/issue/74063/1207154

Tuncal, A., & Altıntaş, O. A. (2025). Human Factors in Aviation and Aerospace. *Human Factors in Aviation*. http://dx.doi.org/10.26650/hfaa.2025.1633491

Valenta, V. (2018). Effects of Airline Industry Growth on Pilot Training. *MAD-Magazine of Aviation Development*, *6*(4), 52-56. https://doi.org/10.14311/MAD.2018.04.06

Vural, S. (2023). Why Are Flight Psychologists Important to Flight Safety? *Journal of Aviation*, *7*(1), 156-160. https://doi.org/10.30518/jav.1220425

Zimmermann, N., Wang, P. H., & Pullen, K. (2022). Fatigue in Aircraft Maintenance Technician Schools. *International Journal of Aviation, Aeronautics, and Aerospace*, *9*(4), 7. https://doi.org/10.58940/2374-6793.1756