Human Factors in Runway Collision: Lesson Learned from the Flight 2213 Accident Using HFACS

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SUMMARY

This research uses a runway collision event as a case study to analyse the complex systemic factors involved in aviation safety. The study applied the Human Factors Analysis and Classification System (HFACS) framework to analyse the Flight 2213 accident, in which an A320 Neo collided with a rescue vehicle during a take-off run. Given the involvement of both the air navigation service provider (ANSP) and the airport operator (AO) in the runway incursion, the analysis was conducted across both organisations. The findings revealed systemic failures at different HFACS levels: the ANSP exhibited deficiencies at the *Preconditions for Unsafe Acts* and *Unsafe Supervision* levels, including technological limitations, an air traffic controller's adverse physiological state, inadequate standard operating procedures, and weak supervision. The AO's failures were identified at the *Organisational Influence* and *Unsafe Supervision* levels, with a poor safety culture, ineffective coordination, and an inexperienced supervisor. The primary unsafe act was the unauthorised runway entry of the rescue vehicle. While each organisation had vulnerabilities at specific HFACS levels, their combined failures spanned all four levels, creating the conditions for the accident. These findings underscore the need for a systemic and integrated safety analysis that encompasses multiple organisation stakeholders to enhance coordination, communication, and risk management between air navigation service providers, airport operators, and airlines. Strengthening safety culture and improving inter-organisational collaboration are critical to mitigating risks and preventing future runway incursions.

KEYWORDS

Aviation Safety, Human Error, Organisational Influence, Runway Incursion, Situation Awareness

Introduction

Defined as "Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and takeoff of aircraft." (ICAO Safety Report, 2024), runway incursions are a critical global safety priority identified by the International Civil Aviation Organization (ICAO, 2024), which significantly contributed to deaths and fatal accidents. With the continuous growth of air traffic, the likelihood of runway incursions could also increase unless enhanced safety measures are implemented. This is illustrated by the Federal Aviation Administration (FAA) 2024 report, which recorded 1,760 runway incursions in fiscal year 2023 and 1,757 incursions in 2024 (FAA, 2024).

Moreover, recent runway incursion accidents, such as those on November 22, 2022, in Lima, Peru, and on January 2, 2024, at Haneda Airport in Tokyo, serve as ongoing reminders that the risk is not yet fully controlled. In August 2024, a document titled the "Global Action Plan for the Prevention of Runway Incursions" (GAPPRI) was published as part of ICAO's Global Aviation Safety Plan and the Global Aviation Runway Safety Action Plan. Coordinated by ICAO, the Flight Safety Foundation, and Eurocontrol, and endorsed by ACI World, CANSO, and IATA, the plan was developed with the participation of over 200 experts from 80 organisations. GAPPRI is based on global and regional data analysis and offers 127 recommendations to enhance safety. These include strengthening aviation personnel training, integrating advanced technologies to improve situational awareness, optimising operational procedures and communications, and improving visual aids and infrastructure design (GAPPRI, 2024).

Significant efforts have been made to understand this phenomenon, and extensive research exists in the literature to address this multidimensional issue. A systematic review conducted by Yan, Boufous, and Molesworth (2024) highlights the key human factors influencing pilot-related runway incursions, categorising them into two main groups: failure to comply with air traffic control (ATC) instructions and positioning errors. The study underscores the importance of improving communication training, enhancing cockpit displays, and improving airport signage as key mitigation strategies (Yan et al., 2024). Another study by Hassan (2021) applied a systemic approach to analysing runway incursion risks and identified contributors including organisational and regulatory shortcomings, poorly communicated notice to airmen (NOTAMs), insufficient automation in aviation systems, and crew resource management (CRM) deficiencies. For example, an analysis of the Air Canada Flight 759 incident at San Francisco International Airport (SFO) revealed that errors in airfield lighting and pilot fatigue contributed to this near-collision event.

From a technological perspective, Omosebi et al. (2023) examine the effectiveness of various safety technologies in reducing runway incursions at U.S. airports. Their findings indicate that Runway Status Lights (RWSL) significantly reduce severe incursions (Categories A and B) by providing immediate and direct alerts to pilots. In contrast, the Airport Surface Detection Equipment Model X (ASDE-X) is deemed less effective due to its reliance on ATC intervention, which can delay hazard recognition. The study highlights the need to prioritise RWSL deployment at high-risk airports with complex runway configurations, along with strategic improvements in airport design to minimise runway intersections (Omosebi et al., 2023).

One of the most widely adopted frameworks for comprehensive accident analyses is the Human Factors Analysis and Classification System (HFACS). Developed by Wiegmann & Shappell (2001), HFACS builds on the Swiss Cheese Model of Reason (1990) by categorising accident causation across four hierarchical systemic levels: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organisational influences. HFACS provides a structured taxonomy that classifies both active failures of operators and latent conditions across the aviation system. Its application has been extended beyond aviation to industries such as maritime, rail, and mining (2019), demonstrating its versatility and effectiveness in accident causation analysis.

The literature surrounding HFACS highlights its effectiveness in investigating accidents or incidents at the various levels of an organisation. Mohandas & Weng (2021) applied HFACS to 75 aviation accidents in Singapore, identifying critical human errors and organisational shortcomings that aligned with official investigation reports. Their findings underscored HFACS's value in classifying both immediate causes, such as skill-based errors, and latent factors, such as training deficiencies and inadequate supervision. Similarly, Small (2020) applied HFACS to the Asiana Airlines Flight 214 crash, revealing how poor pilot training, organisational oversight, and procedural violations collectively contributed to the accident. The study concluded that focusing solely on pilot errors without addressing broader organisational influences leads to incomplete safety interventions. Also, Yan et al. (2025) conducted a HFACS analysis of pilot-related runway incursions in the United States and Australia, identifying teamwork failures and communication breakdowns as the most prominent contributors to runway incursions; *Failure of effectively communicate* and *inadequate communication equipment* being the most frequently observed factors. Also, procedural violations played a significant role across multiple phases of events. At higher system levels, *organisational policy risks not adequately assessed* was the most frequently cited.

Despite HFACS's demonstrated effectiveness, it is found that its 'unit of analysis' is commonly limited to single organisation. This study will apply the framework across two relevant organisations within the analysis of the LATAM Flight 2213 accident to identify the between and within organisational factors, and their interactive dynamics, that contributed to the event. By systematically categorising both active and latent failures, the study seeks to offer insights into pilot behavior, air traffic controller communication, airport infrastructure, and organisational practices. Through this comprehensive approach, the study will provide more robust evidence-based recommendations for improving safety in aviation operations and reducing the occurrence of future incidents or accidents, contributing to the ongoing enhancement of aviation safety management systems.

Methods

The Flight 2213 accident was analysed using HFACS as a case study to identify the causal factors contributing to runway incursions. The accident report of Perú Flight 2213 contains detailed information about the A320 Neo aircraft collision with a firefighter vehicle that was crossing runway 16L at Jorge Chávez International Airport on 18 November 2022. HFACS is a widely used framework, including four levels and eighteen categories related to human factors in flight operations (Wiegmann & Shappell, 2003). This study applied the HFACS framework across the two organisations involved in the accident, the Air Navigation Service Provider (ANSP) and the Airport Operator (AO).

In this work, an air traffic controller and an air traffic manager (both with eight years of experience), as well as two chartered experts in human factors, used HFACS to analyse the accident report of the runway incursion and developed accident prevention strategies.

Results and Discussion

The accident was primarily caused by an unsafe act committed by the driver of rescue vehicle, who entered the runway without authorisation from the ANSP air traffic controller (ATC). The investigation identified two preconditions for unsafe acts within the air navigation service provider organisation: technological environmental factors and adverse physiological state.

Regarding the technological factors, it was found that ATCs at the ANSP tower lacked access to technology that could enhance their situational awareness because they only had binoculars to locate the position of vehicles, which was insufficient to allow a better understand the situation (i.e., weakness of level 1 situation awareness). Additionally, the analysis revealed that the surface controller was undergoing rehabilitation from a broken leg, placing him in an adverse physiological state. This situation would have prevented him from standing up to follow the traffic taking off as part of the ATCO task. These preconditions likely contributed to the occurrence of the accident.

The analysis further indicated that the accident was influenced by deficiencies at the *Organisational Process* level. Specifically, there was an inadequate SOP detailing the duration of the emergency vehicle's response time (the Exercise Time Response (ETR)), resulting in a lack of coordination and communication between the AO and ANSP. Furthermore, there was a lack of adequate procedures regarding the shift change process at the ANSP tower because the outgoing and upcoming shift supervisor did not provide information to the joining controllers regarding the execution of the second ETR exercise.

At the *Unsafe Supervision* level, two contributing factors were identified: inadequate supervision and planned inappropriate operations. There was a lack of supervision within the ANSP tower at the time of the accident and an absence of coordination with the AO regarding the exercise. Notably, there was no unsafe act committed by an operator within the ANSP organisation itself.

For the AO, the investigation revealed two issues at the *Organisational Influence* level: organisational process and organisational climate. The findings indicated a poor safety culture within the AO and an inadequate SOP for the ETR exercise, particularly concerning coordination, and communication. At the *Unsafe Supervision* level, there was a lack of coordination within AO, and the supervisor of the ETR exercise was found to be inexperienced. The identified unsafe act was the unauthorised entrance of the rescue vehicle onto the runway without ATC clearance. Unlike the ANSP, no preconditions for unsafe acts were identified within the AO.

Applying the HFACS model to both organisations involved in the accident – the ANSP and AO – it was revealed that a complementary distribution of failures existed across the four levels of the framework. A summary of this analysis is presented in **Table 1**.

Individually, each organisation exhibited weaknesses at specific HFACS levels while remaining free of failures at others. The ANSP was primarily affected at the *Preconditions for Unsafe Acts* level and the *Unsafe Supervision* level. On the other hand, the AO showed deficiencies at the *Organisational Influence* level and the *Unsafe Supervision* level.

However, when both analyses are combined, failures are present across all four HFACS levels**.** This comprehensive perspective highlights the interdependence of organisational failures. While each entity has its vulnerabilities, their interaction creates an environment conducive to accidents, where every weak link contributes to the outcome. This analysis underscores the need for a systemic and integrated approach to safety, involving both air navigation service providers and airport operators, to address gaps at all levels and prevent future accidents.

Table 1: Summary of findings

HFACS Level	**ANSP**	**AO**	**Combined Organisation**
ORGANISATIONAL INFLUENCE	🟧 Inadequate SOPs: Poor shift change procedures 🟧 Lack of Coordination: Poor communication with the AO	🟧 Poor Safety Culture: Weak internal safety climate 🟧 Inadequate SOPs: Poor coordination and communication for ETR exercise	🟧 Failures at this level in both organisations, but different aspects
UNSAFE SUPERVISION	🟧 Inadequate Supervision: Lack of supervision within the ATC tower 🟧 Planned Inappropriate Operations: No coordination with the AO on the exercise	🟧 Inadequate Supervision: Lack of internal coordination 🟧 Supervisor Inexperience: The ETR exercise supervisor lacked experience	🟧 Failures in unsafe supervision exist in both organisations
PRECONDITIONS FOR UNSAFE ACTS	🟧 Technological Environmental Factor: Lack of ATC situational awareness tools 🟧 Adverse Physiological	🟩 No identified preconditions for unsafe acts	🟧 Present in ANSP and absent in AO

	State: Surface controller recovering from injury		
UNSAFE ACTS	No unsafe acts identified	Unauthorised runway entry by rescue vehicle	Unsafe act present in AO but not ANSP
			ACCIDENT

Color Lexicon

- **Green**: No failure detected at this HFACS level.
- **Orange**: Failure detected at this HFACS level.
- **Red**: The accident occurred due to cumulative failures at four levels.

Conclusion

The runway incursion involving a rescue vehicle was a preventable event resulting from a combination of systemic organisational deficiencies, including inadequate supervision, ineffective communication protocols, insufficient safety culture, and flawed procedural controls. This analysis has highlighted that aviation accidents rarely stem from isolated operator errors but are instead the product of multiple interrelated latent failures across organiational levels. Additionally, this study revealed that while individual organisations exhibit weaknesses at specific HFACS levels, their combined failures span across all four levels, emphasising the interconnected nature of organisational deficiencies. HFACS can provide a comprehensive framework for identifying and mitigating these latent risks, demonstrating its efficacy in aviation safety management.

ICAO has published the GAPPRI, which highlights variability in human performance and miscommunication as leading factors in runway incursions. These findings align closely with the results of this case study. The Flight 2213 accident resulted from systemic failures at multiple levels, including poor organisational coordination, supervisory lapses, environmental complexities, and individual unsafe acts leading to human factors accidents/incidents. The chain of events was initiated by a lack of joint planning and culminated in critical communication breakdowns and procedural violations. Future research may develop artificial intelligence to detect unauthorised vehicle/aircraft movements near active runways and issue timely alerts to air traffic controllers and pilots simultaneously.

To prevent runway incursions and enhance safety, effective coordination between ANSPs, AOs, and emergency teams should be reinforced, with emergency drills scheduled during low-traffic periods. Advanced technology, including real-time runway monitoring and automated clearance systems, must be integrated to improve situational awareness. A strong safety culture should be fostered through transparent reporting mechanisms within a well-structured Safety Management System (SMS). Finally, strict compliance with ICAO regulations, particularly Annex 14 and Annex 19, along with regular safety audits, is crucial to maintaining operational efficiency and mitigating risks.

By implementing these measures, aviation stakeholders can address safety gaps across all four HFACS levels, creating a resilient safety ecosystem that minimises the likelihood of runway incursions and enhances overall operational efficiency.

However, this study is not without limitations. While HFACS is a robust framework, its effectiveness is dependent on the quality and availability of data collected during accident investigations. Incomplete or inaccurate data may lead to an incomplete identification of causal factors, particularly at the higher organisational levels. The integration of HFACS with other safety frameworks, such as Systems-Theoretic Process Analysis (STPA)**,** may enhance the system-wide identification of hazards and provide a more holistic view of aviation safety for runway collision events.

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