

Analysis of Pilot-ATC Communication Factors in Aircraft Accidents and Incidents: A Literature Review from The Perspective of ATS Safety Investigations

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Keywords	Abstract
ATS Safety Investigation; ATC; Pilot-Controller Communication; Runway Incursion; Aircraft Incident; Human Factors	Flight safety is greatly influenced by the effectiveness of communication between pilots and Air Traffic Controllers (ATC). In many aircraft accidents and incidents, communication failures, readback/hearback errors, the use of non-standard phraseology, and limited situational awareness are significant contributing factors. This research aims to analyze the literature related to the relationship between pilot-ATC communication and aircraft accident and incident incidents, especially in the context of Air Traffic Services Safety Investigation. The method used was literature review with stages of identification, selection, analysis, and synthesis of literature from investigation reports, scientific articles, and international aviation safety documents. The results of the study show that unclear communication can trigger runway incursion, loss of separation, clearance errors, and delayed decision-making. Case studies such as the Tenerife Airport Disaster show that a combination of miscommunication, operational pressures, weather, and technological limitations can develop into fatal accidents. The conclusion of this study emphasizes the importance of standardization of phraseology, improving human factors training, implementing readback/hearback discipline, and strengthening safety support systems in ATS operations.

INTRODUCTION

Air Traffic Services or ATS has an important role in maintaining the safety, order, and efficiency of air traffic (Biedermann et al., 2024; Donmez et al., 2022; Ellis et al., 2025; Hendrikse, 2025; Lowth, 2024; Pavlović et al., 2023; Pinto Neto et al., 2023). In the context of aviation safety, communication between pilots and ATCs is one of the main layers of defense to prevent aircraft accidents and incidents. ICAO Annex 13 affirms that the primary purpose of accident and incident investigations is not to find fault or blame on a particular party, but to prevent the recurrence of similar incidents in the future.

One type of incident that is often associated with pilot-ATC communication is runway incursion, which is a condition when aircraft, vehicles, or people are improperly in the runway area used for take-off or landing (Alaydi et al., 2026; Estival, 2025; Mateou & Mateou, 2026; Yan, 2025). The risk of runway incursion involves a complex combination of factors and requires a collaborative approach between aircraft operators, aviation navigation service providers, airports, and regulators (Cavcav, 2025; Huet, 2023; Zhang & Yarde, 2024).

The case of the Tenerife Airport Disaster on 27 March 1977 is an important example in aviation safety learning (Kaur & Sharpanskykh, 2024; Knopfholz et al., 2026). The accident occurred when KLM's Boeing 747 started take-off while the Boeing 747 Pan Am was still

using the runway for taxi. The human factors study of Tenerife highlighted stress factors, group communication under pressure, and group dynamics as important factors contributing to accidents.

Despite numerous studies addressing pilot-ATC communication, several gaps remain unfulfilled (Alaydi et al., 2026; Dassonville, 2025). Existing research tends to be case-specific and has not provided a comprehensive picture of failed communication patterns from the perspective of ATS safety investigation. Furthermore, few studies have systematically synthesized findings from investigation reports, scientific articles, and international aviation safety documents. This study offers novelty through a literature review approach that integrates various literature sources to identify patterns of pilot-ATC communication that contribute to aircraft accidents and incidents within the perspective of ATS Safety Investigation.

Based on this, this literature review is compiled to answer the main question: how do pilot-ATC communication factors contribute to aircraft accidents and incidents in the perspective of ATS Safety Investigation? This study aims to analyze the literature on the relationship between pilot-ATC communication and aircraft accidents and incidents, particularly in the context of Air Traffic Services Safety Investigation. This research is expected to provide both theoretical and practical benefits. Theoretically, this study enriches the body of knowledge in aviation safety, particularly in understanding the role of pilot-ATC communication as a safety factor. Practically, this research benefits air navigation service providers in improving communication procedures and training, regulators in formulating evidence-based safety policies, and future researchers as a reference for further studies on human factors in aviation safety. The research question formulated in this study is: how do pilot-ATC communication factors contribute to aircraft accidents and incidents from the perspective of ATS Safety Investigation?

METHOD

This research used the literature review method with a descriptive-qualitative approach. Literature review is carried out through several stages, namely literature identification, literature selection, content analysis, and synthesis of findings.

The literature was collected from several sources, namely aviation safety investigation reports, scientific articles, ICAO, FAA, NTSB, EUROCONTROL documents, and aviation safety-related journals. Keywords used include: pilot ATC communication, air traffic control incident, runway incursion, aircraft accident investigation, ATS safety investigation, human factors aviation, and readback hearback error.

Inclusion Criteria

1. Discuss accident or incident aircraft.
2. It has a relationship with pilot-ATC, ATS, runway incursion, loss of separation, or human factors.
3. Come from a scientific source, official document, or aviation safety agency.
4. Relevant to aviation safety investigations.
5. Published in Indonesian or English.

Exclusion Criteria

1. It does not discuss the safety aspect of flight.
2. Irrelevant to ATS or pilot-ATC communications.
3. It doesn't have a clear source.
4. It is only in the form of an opinion without a basis for data or analysis.
5. Not related to accident or incident aircraft.

Literature Analysis and Synthesis

1. Pilot-ATC communication.
2. Readback/hearback error.
3. Runway incursion.
4. Human factors and workload.
5. The role of safety technology.
6. Mitigation recommendations in the ATS Safety Investigation.

RESULTS AND DISCUSSION

Pilot-ATC Communication as a Safety Factor

Communication between pilots and ATCs is an important element in air traffic control. ATC instructions must be received, understood, reread, and executed appropriately by the pilot. If an error occurs at one of these stages, the potential for an incident can increase. EUROCONTROL said that important communication factors in runway incursion include incorrect or incomplete readback by pilots and ATCs, especially when conditional clearance is used. This shows that communication is not just an exchange of information, but also a process of safety validation. In operational communication, standard phraseology is necessary to reduce ambiguity. The use of non-standard words or terms may lead to different interpretations between pilots and controllers. In conditions of heavy traffic, bad weather, or busy radio frequencies, the risk of mishearing and misinterpretation is even greater.

Readback and Hearback Errors

Readback is the process of the pilot repeating important instructions from the ATC, while hearback is the process of the ATC re-listening to the pilot's readback to ensure the instructions are read correctly. Failure in this process may cause the aircraft to receive or carry out inappropriate clearance. Readback/hearback errors can be in the form of wrong altitude, wrong runway, wrong callsign, incomplete readback, or incorrect hearback.

Table 1. Examples of readback/hearback errors and potential impacts

Error Types	Example	Potential Impact
Wrong altitude	FL 190 read FL 090	Loss of separation
Wrong runway	Runway 27 reads Runway 25	Runway incursion
Wrong callsign	Instructions received by other aircraft	Clearance deviation
Incomplete readback	The pilot simply replied "roger"	Instructions are not validated
Hearback not performed	ATC does not catch pilot error	Error continues to operational action

Source: Adapted from EUROCONTROL (2004) and ICAO (n.d.)

Runway Incursion as a Result of Communication Failure

Runway incursion is a form of incident that is very risky because it involves a potential collision in the runway area. This risk can arise when the aircraft or vehicle enters the runway without a proper clearance, misunderstands taxi instructions, or when ATC provides a contrary clearance. In the context of ATS Safety Investigation, runway incursion should be analyzed as a system failure, not just an individual fault. Factors that need to be examined include communication, airport layout, visibility, traffic density, unit coordination, procedures, training, and supporting technology.

Tenerife Airport Disaster Case Study

The Tenerife Airport Disaster became one of the most important accidents in the history of aviation safety. The accident occurred when the KLM Boeing 747 started take-off while the Pan Am Boeing 747 was still taxiing on the same runway. In addition to miscommunication, other factors such as low visibility due to fog, traffic density, ground radar limitations, operational pressures, and the use of ambiguous phraseology reinforce the chain of failure. An important lesson from Tenerife is that a single miscommunication can develop into a major accident if there is not enough layer of defense.

Human Factors and ATC Workload

Human factors are an important aspect of ATS Safety Investigation. ATC works in a complex, dynamic, and highly concentrated environment. As traffic density increases, so does the workload of controllers. This can affect the controller's ability to detect conflicts, coordinate, and ensure accurate readback/hearback. In ATS investigations, workload needs to be seen from the number of aircraft controlled, traffic complexity, weather and visibility, inter-unit coordination, condition of communication and surveillance equipment, duration of work, fatigue, and controller experience.

The Role of Technology in Incident Prevention

Technologies such as surface movement radar, A-SMGCS, electronic flight strips, conflict alerts, and runway status lights can help increase situational awareness. However, technology does not completely eliminate risks if human procedures, communication, and coordination are still weak. Therefore, technology must be combined with clear procedures and consistent human training.

Literature Synthesis

Based on the literature reviewed, ATS-related aircraft accidents and incidents are usually not caused by a single factor. Safety events are generally the result of a combination of human, communication, procedure, environmental, and technological factors.

Table 2. Synthesis of literature review findings

Theme	Key Findings	Implications of ATS Safety Investigation
Pilot-ATC communication	Miscommunication may lead to misunderstood clearance	Investigators should review communications records
Readback/hearback	Incomplete readbacks increase the risk of errors	There is a need for a communication discipline audit.
Runway incursion	Risks arise due to clearance, traffic position, and awareness	Need runway occupancy analysis and tower coordination
Human factors	Workload and operational pressures affect decisions	Need to evaluate staffing, fatigue, and complexity
Technology	Alert systems help, but do not replace procedures	Need to integrate technology with SOPs and training
Safety investigation	The purpose of an investigation is prevention, not blame	Recommendations must be system-based

Source: Literature synthesis from EUROCONTROL (2004; 2017), ICAO (n.d.), McCreary (1998), and NTSB (n.d.)

Mitigation Recommendations

1. Improved readback/hearback discipline for all critical clearances, especially runway, altitude, heading, and frequency change.
2. Use ICAO standard phraseology consistently to avoid ambiguity.
3. Avoid using non-standard words like "OK" or "roger" without a full readback on important instructions.
4. Conduct recurrent human factors training for ATCs and pilots, including high-pressure communication.
5. Improve situational awareness controllers through briefing, scanning techniques, and traffic position monitoring.
6. Optimizing surveillance technology and alerting systems, especially at airports with heavy traffic.
7. Conducting a system-based safety investigation does not only focus on individual errors.
8. Develop safety recommendations that touch on procedures, training, technology, and organization.

CONCLUSION

This literature review shows that pilot-ATC communication is an important factor in preventing aircraft accidents and incidents. Communication failures can occur in the form of readback/hearback errors, non-standard phraseology, misinterpretation clearance, or lack of situational awareness. In the case of runway incursion and loss of separation, communication failures often interact with other factors such as workload, weather, airport layout, technology limitations, and operational pressures. In the perspective of ATS Safety Investigation, accidents and incidents must be analyzed systemically. The purpose of the investigation is not to find the

blame, but to find contributing factors and make preventive recommendations. Therefore, improving standard phraseology, human factors training, readback/hearback discipline, and the use of safety support technology are important steps to strengthen the safety of ATS operations. Based on these findings, it is recommended that air navigation service providers strengthen the implementation of standard phraseology in accordance with ICAO provisions and conduct regular audits of communication discipline, including readback/hearback procedures, to ensure all critical clearances are properly validated. For ATCs and pilots, recurrent human factors training should be enhanced, particularly in high-pressure communication scenarios, and situational awareness should be improved through briefing techniques, scanning methods, and traffic position monitoring. Regulators and aviation authorities should develop and enforce evidence-based policies that integrate technology, procedures, and training, while ensuring that safety investigations remain system-based rather than focused on individual errors. For future researchers, it is recommended to conduct empirical studies on the effectiveness of readback/hearback audits in reducing communication errors, as well as comparative studies between different air navigation service providers regarding the implementation of safety support technologies such as A-SMGCS, conflict alerts, and runway status lights.

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