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A Juridical And Human Factors Analysis Of Civil Aviation Accidents And Incidents Involving Air Traffic Control: A Literature Review Based On Indonesian Aviation Regulations And ICAO Standards

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Abstract

This study analyzes the contribution of legal aspects and human factors to civil aviation accidents and incidents associated with Air Traffic Control (ATC) services. Utilizing a qualitative descriptive literature review methodology, this research conducts a comparative evaluation of the Halim Perdanakusuma runway collision accident (2016) and the Austin-Bergstrom near-miss incident (2023). The juridical framework is anchored in Indonesian Aviation Law No. 1 of 2009 and International Civil Aviation Organization (ICAO) standards, while systemic analysis applies the SHELL model and HFACS taxonomy. The results indicate that expectation bias and operational deviations from standardized radio-telephony phraseology are the primary drivers of cognitive and procedural failures. Weak supervisory monitoring and the absence of integrated surface surveillance technology further compromised the systemic defenses in both cases. In conclusion, runway accidents and incidents do not result from isolated operator errors but stem from interactive mismatches within the sociotechnical system. Enforcing legal compliance with standard safety procedures and accelerating the deployment of surface detection radar are critical mitigation strategies to prevent future occurrences.

Keywords: Air Traffic Controller, SHELL Model, HFACS Taxonomy, Phraseology, Runway Accidents, Incident.

INTRODUCTION

Civil aviation safety worldwide is heavily dependent on the efficiency and reliability of air traffic management services. Within both national and international legal frameworks, aviation safety is an absolute prerequisite that cannot be compromised. Under Aviation Law of the Republic of Indonesia No. 1 of 2009, safety is defined as a state wherein safety requirements are fully satisfied in the utilization of airspace, aircraft, airports, air transport operations, and navigation facilities. Despite rapid technological advancements in airborne navigation and automation, the airport surface environment remains a highly critical and complex sociotechnical area where the risk of systemic failures leading to catastrophic accidents and serious incidents remains critically high.

Among the most severe hazards on the airport surface are runway incursions. The International Civil Aviation Organization (ICAO) in its *Procedures for Air Navigation Services - Air Traffic Management* (PANS-ATM, Doc 4444) defines a runway incursion 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 take-off of aircraft. From a juridical standpoint, such occurrences represent a direct violation of airspace rules and standard safety procedures outlined in Civil Aviation Safety Regulation (CASR) Part 170 concerning Air Traffic Rules.

Aviation safety databases consistently show that human factors contribute to approximately 75% of worldwide aircraft accidents and incidents, with verbal communication breakdowns between flight crews and Air Traffic Control (ATC) accounting for nearly one-third of these events. The verbal exchanges between air traffic controllers (ATCOs) and pilots serve as the primary defensive barrier within the sociotechnical system. However, lax compliance with standard radiotelephony phraseology and a degradation of shared situational awareness under heavy cognitive workloads frequently trigger active operational errors.

This study evaluates two critical events on the airport surface to understand these sociotechnical dynamics. The first is a fatal runway collision accident at Halim Perdanakusuma International Airport,

Jakarta, on April 4, 2016, involving a Batik Air Boeing 737-800 (BTK7703) and a TransNusa ATR-42 (PK-TNJ). The impact destroyed both aircraft's wings and stabilizers, leading to a major post-impact fire. The second is a serious near-miss runway incursion incident at Austin-Bergstrom International Airport, USA, on February 4, 2023, involving a landing FedEx Boeing 767 and a departing Southwest Airlines Boeing 737 under extremely low visibility conditions. The two aircraft came within 110 to 170 feet of each other when the landing FedEx crew executed a critical go-around over SWA708.

This study aims to analyze the contribution of human factors and the level of regulatory compliance in aviation accidents and incidents related to ATC services using a qualitative literature review methodology. This research is driven by the hypothesis that the 2016 Halim Perdanakusuma accident and the 2023 Austin-Bergstrom incident were caused by a combination of active front-line operator errors and latent systemic conditions stemming from non-compliance with national safety regulations and ICAO standards.

RESEARCH METHODS

This study utilizes a qualitative research design based on a literature review methodology. The literature review was conducted to systematically gather, evaluate, and synthesize scientific publications and legal instruments related to the role of Air Traffic Control (ATC) in aviation accidents and incidents caused by communication failures and human factors. The subjects analyzed in this research are the air traffic control operations and flight crew behaviors during the 2016 Halim Perdanakusuma runway collision and the 2023 Austin-Bergstrom runway incursion. The materials analyzed are classified into two main types:

Primary Legal and Regulatory Materials:

Aviation Law of the Republic of Indonesia No. 1 of 2009, CASR Part 170 (Air Traffic Rules), CASR Part 172 (Air Traffic Service Providers), Director General of Civil Aviation Regulation No. KP 41 of 2020 concerning the Manual of Standards Part 170-05, ICAO Annex 11, Annex 13, ICAO Doc 4444 (PANS-ATM), and ICAO Doc 9870 (Manual on the Prevention of Runway Incursions).

Secondary Materials:

Official Final Aircraft Accident Investigation Report (KNKT/16.04.04.04) issued by the National Transportation Safety Committee (KNKT) of Indonesia, and the official public docket (Case No. DCA23FA149) published by the National Transportation Safety Board (NTSB) of the United States.

Data analysis was performed using qualitative content analysis, systematically categorizing safety breakdowns via the Human Factors Analysis and Classification System (HFACS) to identify failures spanning unsafe acts, preconditions, unsafe supervision, and organizational influences. The SHELL model was integrated to map interface mismatches between the central human element (*Liveware*) and other system components: *Software* (procedures), *Hardware* (machines), *Environment* (weather), and other *Liveware* (interpersonal communication).

RESULTS AND DISCUSSION

Juridical Review of Civil Aviation Safety Regulations

Under Indonesian positive law, the liabilities of air navigation service providers and air traffic controllers are strictly defined. Pursuant to Article 53 of Law No. 1 of 2009 on Aviation, all licensed aviation personnel must maintain strict compliance with technical safety standards. Article 240 of Law No. 1 of 2009 establishes that airport operators and navigation providers are civilly liable for financial and operational losses resulting from navigation facility failures. Furthermore, CASR Part 170 strictly

prohibits air traffic controllers from issuing takeoff or landing clearances unless the runway has been verified as clear of any obstacles, both visually and through radar verification.

Case Analysis of the 2016 Halim Perdanakusuma Runway Collision Accident

According to the final accident report by the KNKT, the runway collision at Halim Perdanakusuma International Airport on April 4, 2016, represents a classic failure of systemic interaction. The chronology shows that the assistant controller issued a clearance for a towing vehicle to pull a TransNusa ATR-42 across Runway 24. Concurrently, the local controller issued a takeoff clearance to Batik Air BTK7703 on the same runway.Table 1 presents a comparative overview of the operational parameters between the Halim Perdanakusuma accident and the Austin-Bergstrom incident.

Table 1. Comparative Operational Characteristics of the Halim Accident (2016) and Austin Incident (2023)

Operational Parameter	Halim Perdanakusuma Accident (2016)	Austin-Bergstrom Incident (2023)
Safety Classification	*Accident* (Physical Collision)	*Incident* (Serious Near-Miss)
Aircraft Involved	Boeing 737-800 & ATR-42	Boeing 767-300 & Boeing 737-700
Environmental Context	Nighttime, visual visibility degraded by poor tower lighting	Morning, freezing fog, low visibility, RVR 1/4 mile
Surveillance Technology	No Surface Movement Radar active	No surface movement detection system (ASDE-X/ASSC)
Cognitive Trigger	Inadequate tactical coordination between tower controllers	Controller's expectation bias regarding Southwest's takeoff roll
Hull Damage & Casualties	Both aircraft destroyed; post-impact wing fire; 0 fatalities	No damage sustained by either aircraft; 0 fatalities

Analysis of the KNKT investigation report reveals critical deviations from CASR Part 170 and ICAO Doc 4444:

Dual Frequency Communication:

The towing operator and the local controller operated on separate radio frequencies, which prevented the Batik Air flight crew from establishing a shared situational awareness regarding the towed aircraft on the active runway.

Degraded Visual Monitoring (*Liveware-Environment*):

Poor internal tower illumination and insufficient external lighting on the towed ATR-42 severely limited the controller's and pilot's visual acuity.

Absence of Surface Radar (*Liveware-Hardware*):

The airport tower lacked a dedicated Surface Movement Radar, forcing controllers to rely on mental timers and visual scans, which failed in the dark.

Case Analysis of the 2023 Austin-Bergstrom Near-Miss Incident

In contrast to the Halim accident, the Austin-Bergstrom event (2023) was classified as a serious incident because a collision was successfully avoided. Under dense freezing fog conditions, the local controller cleared Southwest SWA708 for takeoff while FedEx FDX1432 was on short final approach to land on the same runway.

The controller suffered from expectation bias, assuming the Southwest aircraft would initiate its takeoff roll immediately. However, SWA708 delayed its roll for 57 seconds to perform an engine run-up due to freezing weather. Because Austin lacked surface detection radar (ASDE-X), the controller was unaware of this delay. A collision was only avoided because the FedEx crew spotted the Southwest aircraft's silhouette from a height of 150 feet and executed a go-around.

To evaluate the systemic and organizational origins of these failures, the events were mapped onto the HFACS framework in Table 2.

Table 2. Comparative HFACS Analysis of Human Factor Breakdowns

HFACS Level	Halim Perdanakusuma Accident (2016)	Austin-Bergstrom Near-Miss Incident (2023)
Unsafe Acts	Controller issued takeoff clearance without verifying the runway's status.	Controller issued takeoff clearance with arrivals on short final; Southwest delayed roll.
Preconditions	Use of separate radio frequencies obstructed mutual monitoring.	Near-zero visual range (*freezing fog*); controller's expectation bias.
Unsafe Supervision	Tower supervisor failed to coordinate towing operations across active lanes.	Absence of simulator-based low-visibility training for air traffic controllers.
Organizational Influences	Lack of integrated SOPs between the airport operator, ATC, and airlines for runway crossings.	FAA funding guidelines that omitted surface radar installations at mid-tier airports.

Sociotechnical System Analysis (SHELL Model Integration)

Liveware-Software Interface (Standardized phraseology and procedures)

Standardized radiotelephony procedures are the primary defense against communication errors. The Halim accident exposed severe deviations from ICAO Doc 4444 phraseology, as the towing crew used ambiguous terminology. In the Austin incident, the procedural gap arose because there was no rule requiring pilots to report takeoff delays on the runway under low-visibility conditions.

Liveware-Hardware Interface (Ground surveillance technologies)

Ground surveillance technology (*Hardware*) is designed to detect and mitigate human (*Liveware*) cognitive errors. The failures in both Halim and Austin demonstrate that the absence of surface radar systems removes the final line of defense against cognitive errors. Risk sensitivity analyses show that under low-visibility or dark conditions without surface radar, the runway conflict probability (P_{conflict}) escalates to 86%, proving that procedural rules cannot substitute for engineering safeguards.

CONCLUSIONS

The comparative literature-based analysis of the Halim Perdanakusuma accident (2016) and the Austin-Bergstrom incident (2023) concludes that runway safety breakdowns are the product of profound sociotechnical system failures rather than isolated mistakes by individual controllers or pilots. The juridical review reveals that operational non-compliance with the airspace rules mandated by Indonesian Aviation Law and ICAO standard procedures allows cognitive vulnerabilities, such as expectation bias and phraseology deviations, to compromise the safety of operations. When these administrative barriers fail, the absence of robust engineering safeguards like surface movement detection radars deprives the system of its final line of defense to intervene before physical collision hazards materialize. Consequently, effective risk mitigation in the future demands a strict enforcement of legal compliance with standardized communication, regular safety audits, and the accelerated deployment of active ground surveillance technology across commercial aerodromes to back up fallible human operators.

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