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The Impact of Human Factors on the Safety of Airport Ground Operations

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Abstract

This paper provides an extensive overview of the contribution of human factors in airport ground operations safety. The movement area, one of the most critical areas of the airside, is prone to risks and threats related to human action or inaction, which can lead to an aviation accident. Acknowledging the natural human tendency to err and the impossibility of eliminating it entirely, the aviation sector faces enormous challenges in reducing this factor.

The aim of this research was two-fold:

- First, to provide a general overview of the human factors concept;
- Second, to illustrate the importance of human factors as a contributing factor in aviation accidents, specifically in the context of airport ground operations.

In trying to achieve this objective, the research employed a case study method, investigating a myriad of aviation accidents so as to elucidate the human factors implicated within such accidents. The problem focus of the study was outlined as follows: What is the implication of human factors within airport ground operations? To address this research question, a comprehensive research methodology was employed, drawing on an expansive array of methodologies. The methods applied were analysis and synthesis, extensive review of past literature, abstraction, observation, and inference. The findings derived are presented in the conclusion section.

Keywords: airport, airport ground operations, aviation occurrences, human factors, safety

1. Introduction

Ground operations in an airport reflect a sophisticated process that needs to be implemented with the utmost safety standards (Compa, 2013, p. 84). The ground traffic area, although subject to stringent aviation laws, is comparatively more accessible to ground handlers for airlines operating at an airport's ground facilities and infrastructure than taxiways and runways. Ground handlers are required to comply with established standards that include the restriction of speeds and the use of personal protective gear. Nonetheless, the existence of numerous boarding agents who operate frequently under time constraints constitutes conditions that may result in aviation-related accidents (Antalyali, 2019). Statistically, most incidents occur during the phase of aircraft pushback and towing (32%), during arrival and departure of aircraft (24%), and during aircraft weight and balance issues (20%) (Muecklich et al., 2023, p. 1). The incidents have been found to lead to injuries to staff and/or damage to assets, and estimated costs are a staggering USD 10 million annually (Sofema Aviation Services, 2025).

2. Historical background

Over the span of 121 years, substantial advancements in aviation safety have been achieved across all aspects, driven by scientific and technological advancements (Materna et al., 2023, p. 173).

In the pioneering days of aviation, causes were sought in incidents caused by a technical factor, e.g., a power unit failure or an inappropriate choice of construction materials (Firlej, 2021, p. 102). The reliability of any newly developed design could only be assessed in the air by trial and error. Design faults and errors on the part of pilots, often due to unfamiliarity with aerodynamic principles, were primarily responsible for aviation accidents (Augustyn & Firlej, 2022, p. 10). The 1970s marked the peak of the role of human factors in the causation of aviation events.

By the late 1990s, it was accountable for 80–90% of accidents, as assessed by the accident investigation authorities in their final reports. During this period, mistakes on the part of technical personnel, air traffic controllers, and flight crews were predominant. To counter these causes, training modules were conducted, such as Crew Resource Management (CRM), which paved the way for the contemporary concept of Threat and Error Management (TEM) that is still utilized today (Firlej, 2021, p. 30). By the beginning of the first decade of the 21st century, the rate of human factors in incidents had fallen to a percentage of 50–60%, and it was acknowledged that human error can occur in any aspect of the safety system (Lasota, 2018, p. 97).

Studies have shown the paramount significance of cooperation of all aviation stakeholders with respect to safety (Augustyn & Firlej, 2022, pp. 20–21). Accidents still occur, mostly due to the significant impact of human factors, despite the utilization of complex and reliable systems (Materna et al., 2023, p. 173).

3. Organization of transport using intermodal technologies

Literature on human factors issues is quite extensive. Though it addresses issues related to flight crew errors, it has a peculiar lack of focus on errors committed by record handling agents. The writer stresses the significance of this aspect, arguing that it cannot be ignored due to its critical role in ensuring the proper preparation of aircraft for flight and managing the safe handling on arrival and prior to departure, in conformity with the laid-down Standards and Recommended Practices (SARPs), manuals, guidelines, or the internal procedures of the handling organization.

4. The human element in the context of airport ground operations

The problem of human factors in ground handling operations at airports is complex and has been a concern for researchers interested in identifying both positive and negative factors affecting the performance of tasks undertaken by boarding agents. Numerous factors are often mentioned in literature (Augustyn, 2012, p. 43):

- Biometeorological factors;
- Pressure or temperature changes;
- Excess of information;
- Fatigue;
- Illusions;
- Ignorance of hazards;
- Monotony of the work environment;
- Requirement of focused efforts;
- Noise;
- Fast rate of work;
- Situational awareness;
- Stress;
- Time constraints.

Not all mistakes result in a dire situation; however, the potential exists and must be considered when dealing with ground handling services at airports. There are instances in which ground staff fail to wear personal protective equipment against environmental hazards, as evidenced by the following photograph.

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Figure 1. The Ground air traffic coordinator setting up a Boeing 737-400 airliner on one of the parking stands.
Source: the author's own work.

As evident in Figure 1, the ground air traffic coordinator, or marshaller, is spotted without protective earmuffs, therefore subjecting him to the possible danger of noise-induced hearing loss. During a wait for a flight at Hurghada International Airport (HRG/HEGN), it was observed that ground handling staff were using a tow bar that had punctured tires. The oversight resulted in one of the spare wheels moving unpredictably across the airfield. These violations are a clear contravention of current aviation rules, with the potential to trigger an aviation incident.

5. Selected definitions "human factors"

The phrase "human factors" has been described in numerous ways and is subject to a variety of interpretations resulting from the complex nature of human beings, with their inborn abilities and limitations. This phrase is commonly applied in scientific disciplines and occupational fields, and is also referred to as the initial definition of ergonomics. The multidimensionality of the notion makes it difficult to present a precise definition, a fact supported by an extensive literature review. Therefore, this problem requires further examination and the application of modern scientific research and theory to improve safety in the future (Firlej, 2019, pp. 27–28).

For the purposes of this research, the definition of the human factors concept presented below was utilized. It primarily concerns flight crews, but boarding agents are also mentioned. The definition states: "the insufficient actions of pilots and others on the conditions, which led to the accident or were not able to rule it out when influenced by circumstances beyond human control and where there was a potential opportunity to minimize or mitigate the danger" (Augustyn, 2012, p. 43).

Conversely, the Manual on Human Performance for Regulators (Doc 10151), issued by the International Civil Aviation Organization (ICAO), suggests that the terms "human factors" and "human performance" are often used interchangeably because of their intrinsic interdependence (ICAO, 2021, pp. 1–2):

- "Human performance refers to how people perform their tasks. It represents his or her contribution to the functioning of the system";
- "Human factors refers to the application of what we know about people, their abilities, characteristics and limitations, to the design of the equipment they use, the environments in which they operate and the tasks they perform".

6. Taxonomy of accidents in the airport ground movement area

A comprehensive overview of the various contributing factors and the corresponding definitions of the term "human factors" is necessary to determine the types of accidents that occur in the context of airport ground movement. Annex 13 to the Convention on International Civil Aviation: Aircraft Accident and Incident Investigation classifies three fundamental types of aviation occurrences: incident, serious incident, and accident. The literature provides a different classification of these occurrences (Augustyn, 2012, p. 122) (Figure 2).

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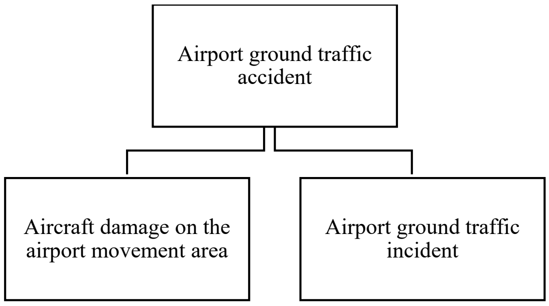

Figure 2. Taxonomy of accidents in the airport ground movement area. Adopted from: S. Augustyn. Copyright 2012 by AR-Aviation Resources.

The definition of "aircraft damage on the airport movement area" is: "any occurrence which causes damage to the aircraft necessitating repairs, regardless of whether or not the operator's staff, the ground handling company, or third parties are held responsible. This definition encompasses all occurrences that take place from the time the aircraft arrives at the parking stand until it taxis and departs under its own power. It is essential to mention that events which are classified as occurrences do not incorporate damages which arise during taxiing, towing of the aircraft to or from the maintenance facility, or in the parking area situated on the maintenance base" (Augustyn, 2012, p. 122).

"Airport ground traffic incident" can be defined as: "an incident, not an accident, pertaining to ground handling or equipment used for the handling of aircraft, which influences or may potentially influence the safety of flight operations. This definition includes reported incidents that did not involve injury to employees and/or damage to property" (Augustyn, 2012, p. 122).

7. Taxonomy of airport ground damage incidents

The cited taxonomy of airport ground handling accidents is general; therefore, it is necessary to understand the ground operation phases in which the probability of such occurrences is high. According to the author team of SKYbrary, an electronic repository of safety knowledge related to aviation operations, air traffic management, and general aviation safety (SKYbrary, 2025), the following phases are particularly prone to incidents:

- Maintenance;
- Passenger boarding bridge, which the fuselage, especially the doors, and the engines are most susceptible to being damaged;
- Towing, in which accidents at this phase primarily lead to damage in the landing gear, the wings, or the empennage;
- Taxing, in which tip damage to the wings is the primary result of such accidents.

Ground damage incidents do not pose an immediate threat to flight safety, as it can be noticed and reported. However, two significant problems have been identified with respect to the efficiency of reporting systems (SKYbrary, 2025):

- Underreporting incidents is brought about by several reasons, including an unwillingness to face the potential consequences or believe that the event itself was not significant. The use of Just Culture principles has been found to bring about a change for the better in this matter;
- Although the events are reported, the data gathered is hard to analyze. With various departments using different error-reporting systems that operate independently, the ability to conduct a comprehensive whole-system analysis is compromised. Thus, errors with the same causes, whose culmination could be an incident, may be logged in various locations.

Although the elimination of ground damage incidents is not possible, their frequency may be minimized and impact on the safety of subsequent operations reduced by using the following steps (SKYbrary, 2025):

- Firstly, there is a need to create and sustain a culture of reporting. People's reluctance to report matters has the potential to halt the identification and fixing of issues, which can continue for a long time and finally contribute to accidents;
- Secondly, the establishment of clear-cut and specific procedures, with provisions for the rectification of bad procedures, is of utmost importance;
- Thirdly, commercial pressure must also be removed. There has to be a line set between safety and efficiency, just as there is a line setting personnel priorities. There should be no compromise with safety and efficiency if there ever was an optimal situation;
- Lastly, determining hazards during the course of investigations must be prioritized over the strong focus on human error.

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8. Ramp Error Decision Aid (REDA) tool

The Ramp Error Decision Aid (REDA) tool, developed in 2016 by the aviation company Boeing Company, is a useful instrument that can be applied in the analysis of human factors incidents of airport ground operations (Boeing, 2016, p. 1).

The REDA is a reactive tool as it is used only following the occurrence of an accident or incident. It provides information about the human aspects of the ground handling process and respondents' perceptions regarding the frequency of particular incidents (Balk et al., 2010, p. 18). It is an instrument based on cognitive factors that cause procedural errors by record handling agents (GAIN, 2003, p. 42).

The philosophy underpinning the REDA is premised on the following (Balk et al., 2010, p. 18):

- There are no deliberate failures;
- Failures result from an abundance of interconnected factors;
- Most of these are part of the organizational process and can be remedied to prevent recurrence.

Violations and mistakes occur due to enabling factors that affect the success of ground operations at an airport. To understand their nature, a socio-technical tool has to be utilized (Table 1). In most cases, other boarding agents are able to make the same error or violation that led to an aviation accident. It is estimated that management is responsible for about 80–90 % of the causal factors, and employees are responsible for about 10–20 %. By applying preventive measures, one can reduce the possibility of a recurrence of an aviation accident occurring in the future.

Table 1. Contributing factors affecting the efficiency of airport ground operations

Plate handling agent	Direct environment	Supervision	Organizational philosophy
- Abilities - Knowledge - Other qualities - Skills	- Communications - Design - Facilities - On-the-job training - Teamwork - Time pressure - Weather	- Delegation of authority - Feedback - Instruction - Organizing - Performance management - Planning - Prioritizing - Team building	- Continuity - Improving the quality of training - Policy - Procedures - Processes - Selection

Source: Adapted from: "Ramp Error Decision Aid (REDA). User's Guide" by Boeing. Copyright 2016.

In this case, the ground handling agent is under supervision in an open working environment, in line with the organization's established policies, processes, and procedures. Any of the enablers can affect the effectiveness of airport ground operations and, at the same time, the performance of employees, leading to the failure of the safety system, which is a causal factor in aviation incidents (Boeing, 2016, p. 7) (Figure 3).

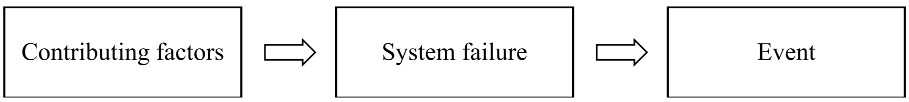

Figure 3. Simplified REDA model. Adopted from: Boeing. Copyright 2016.

The failure model of a safety system indicates a probabilistic relationship between the causes of a safety system's failure and the relationship between a safety system failure and an aviation accident (Boeing, 2016, pp. 8–9) (Figure 4).

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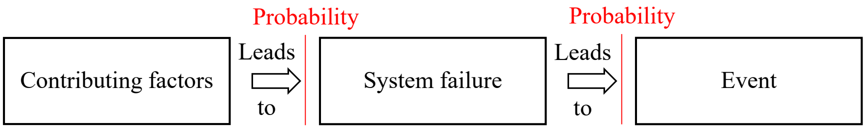

Figure 4. Probabilistic REDA model. Adopted from: Boeing. Copyright 2016.

Figure 5 shows the option where a violation results in an air incident.

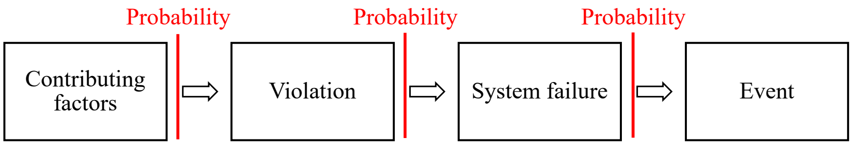

Figure 5. The REDA model with a breach leading directly to a security system failure. Adopted from: Boeing. Copyright 2016.

In some cases, errors and breaches collectively lead to security system failures (Figure 6).

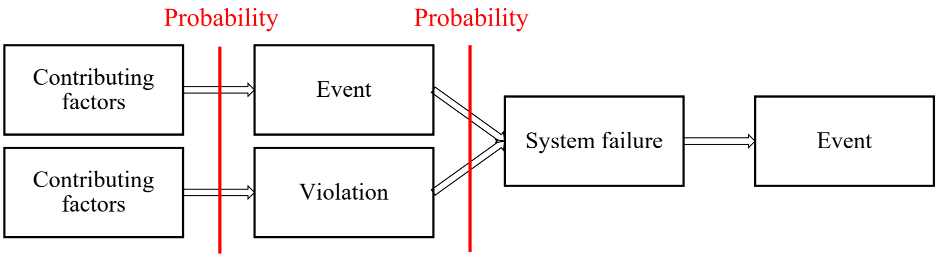

Figure 6. REDA model with a breach causing the plate service agent to miss a fault-induced security system failure. Adopted from: Boeing. Copyright 2016.

There are several violations that lead directly and indirectly to the occurrence of an aviation incident (Figure 7).

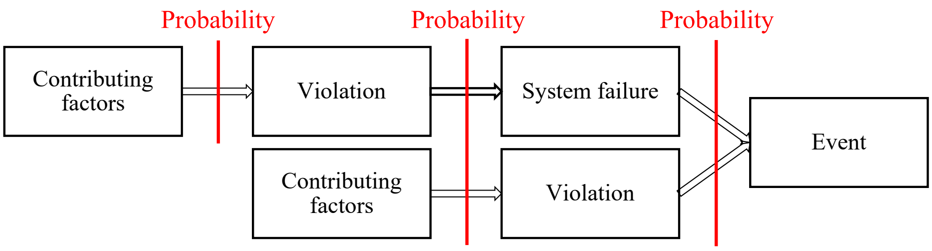

Figure 7. Combined violation model. Adopted from: Boeing. Copyright 2016.

Combining all the previous models yields a target REDA model (Figure 8) that encompasses both defects and violations.

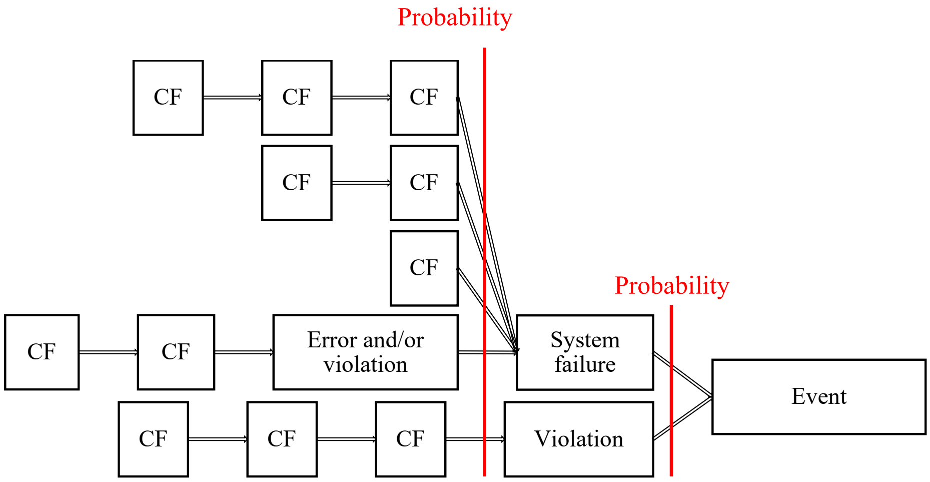

Figure 8. Target REDA model. Adopted from: Boeing. Copyright 2016.

Figure 9 shows the steps in investigating the circumstances and causes of aviation incidents involving human factors in airport ground operations.

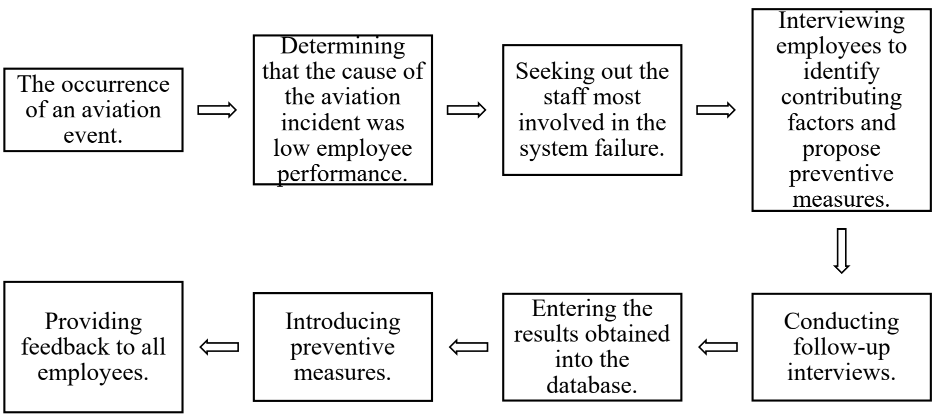

Figure 9. Stages of investigation of the circumstances and cause of aviation incidents involving the human factor in airport ground operations. Adopted from: Boeing. Copyright 2016.

9. Accident involving ATR-72 passenger aircraft and Mulag airport tractor cab

On July 14th, 2011, after landing at Warsaw Chopin Airport (WAW/EPWA) and following its run-in, an ATR-72 passenger aircraft operated by Polish airline Eurolot began taxiing to the parking position. In the meantime, the Mulag airport tractor driver, after completing his task on the apron, was moving along the security line on taxiway A4. At parking stands 37 and 16, at the intersection of the service road and taxiway M2, the vehicle collided with a taxiing ATR-72 passenger aircraft. The driver of the Mulag tractor was injured in the head due to the crash and was hospitalized. The airport vehicle and aircraft were damaged beyond repair. There were adverse meteorological conditions at the time of the accident – heavy rain and lightning, which reduced visibility (MTBiGM - PKBWL, 2011, pp. 3–4).

During the investigation, the State Commission on Aircraft Accidents Investigation (SCAAI) determined that the cause of the air incident was the inability of the operator of the Mulag airport tractor to duly monitor the ground traffic zone.

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Contributory factors to the incident were (MTBiGM – PKBWL, 2011, p. 4):

- Heavy rain with lightning;
- Glare reflected from the surface of the airport apron, which made visibility difficult from the airport tractor cab;
- Mulag airport tractor cab design, whose left front pillar can partially or completely block off the contour of the taxiing aircraft;
- The closeness of the service road to the M2 taxiway.

Figure 10. Damaged engine blades, landing gear nacelle and fuselage skin of ATR-72 passenger aircraft. Adopted from: MTBiGM – PKBWL. Copyright 2011.

Figure 11. Damaged *Mulag* airport tractor cab. Adopted from: MTBiGM – PKBWL. Copyright 2011.

10. An incident involving Airbus A320neo passenger aircraft and a water supply vehicle

On January 7th, 2021, at Lech Walesa Gdansk Airport (GDN/EPGD) prior to an Airbus A320neo passenger aircraft operated by Hungarian low-cost carrier Wizz Air on a flight from Stockholm (NYO/ESKN), a water supply truck became wedged inside the landing gear. No one was killed. Due to the magnitude of the accident, no action was taken to investigate the situation or determine the cause of the aviation accident. (Korolczuk, 2021)

Figure 12. Damaged landing gear shin of Airbus A320neo passenger aircraft and water supply vehicle on board. Adopted from: Korolczuk. Copyright 2021.

11. Incident involving Boeing 787-8 Dreamliner passenger aircraft and a passenger boarding bridge

One of the recent aviation accidents due to human factors in airport ground operations occurred on June 27th, 2024, at Warsaw Chopin Airport (WAW/EPWA) while towing a LOT Polish Airlines Boeing 787-8 Dreamliner from the hangar to the terminal to the parking stand. During the process, the tow truck driver erred in measuring the distance and got the passenger boarding bridge entangled, causing damage to the left engine cover (TVN24, 2024).

Figure 13. Damaged left engine cover due to collision with passenger boarding bridge. Adopted from: TVN24. Copyright 2021.

12. Summary

The results of the research procedure allow the following conclusions to be made:

- First, in terms of human factors issues, a distinct identification of known and prospective areas of problems with respect to airport ground operations, particularly those addressing subsystems and functional areas of the security system;
- Secondly, even with the implementation of diverse methodologies, tools, and techniques aimed at neutralizing the adverse impact of human factors, new threats and risks will still remain in emerging areas, thereby compromising the safety of airport ground operations.

It is crucial to emphasize the urgent need for research in the sphere of human issues, as they are currently the most fragile link in the chain of security. At the same time, it is necessary to identify and address emerging problem areas, which will ultimately lead to enhanced security in the future.

Declaration of interest

The author declares that he has no known competing commercial interests or personal relationships that could have appeared to influence the work reported in this article.

References

1. Antalyali, M. (2016, May 20th). *Accidents and Incidents on Commercial Airport Ramps*. https://www.linkedin.com/pulse/accidents-incidents-commercial-airport-ramps-mustafa-antalyali/
2. Augustyn, S. (Ed.). (2012). *Obsługa naziemna lotniska (ground handling)*. AR-Aviation Resources.
3. Augustyn, S., & Firlej, M. (2022), Ewolucja podejścia do bezpieczeństwa w lotnictwie. *Studia i Materiały Centralnej Biblioteki Wojskowej im. Marszałka Józefa Piłsudskiego*, *1*(17) 2022. https://doi.org/10.5281/zenodo.6805131
4. Balk, A. D., & Bossenbroek J. W. (2010). *Aircraft Ground Handling and Human Factors. A comparative study of the perceptions by ramp staff and management (Report No. NLR-CR-2010-125*), NLR Air Transport Safety Institute – Research & Consultancy. https://www.easa.europa.eu/sites/default/files/dfu/Aircraft-Ground-Handling-and-Human-Factors-NLR-final-report.pdf
5. Boeing (2016). *Ramp Error Decision Aid (REDA). User's Guide*. https://sassofia.com/wp-content/uploads/2017/05/Reda_Users_Guide_V-8_September2013.pdf
6. Compa, T. (2013). Obsługa statków powietrznych w porcie lotniczym. *Logistyka*, *6*/2013, pp. 84–94.

Safety & Defense 11(1) (2025)
DOI https://doi.org/10.371010.37105/sd.249

7. Firlej, M. (2019). *Czynnik ludzki w wypadkach lotniczych* [Unpublished bachelor's thesis]. Akademia Sztuki Wojennej.
8. Firlej, M. (2021). *Wybrane metody badania wypadków lotniczych* [Unpublished master's thesis]. Akademia Sztuki Wojennej.
9. GAIN (2003). *Guide to Methods & Tools for Airline Flight Safety Analysis*. GAIN Working Group B, Analytical Methods and Tools. https://skybrary.aero/sites/default/files/bookshelf/237.pdf
10. Korolczuk, M. (2021, January 7th). *Stłuczka z udziałem samolotu na lotnisku w Gdańsku*. https://www.trojmiasto.pl/wiadomosci/Stluczka-z-udzialem-samolotu-na-lotnisku-w-Gdansku-n152166.html
11. Lasota, M. (2018), Czynnik ludzki w wybranych modelach powstawania wypadków lotniczych. *Obronność – Zeszyty Naukowe Wydziału Zarządzania i Dowodzenia Akademii Sztuki Wojennej*, *3*(27)/2018, pp. 72–97.
12. Materna, M., Maternová A., Kamenická D., & Chodelka F. (2023), The Influence of Human Factor on Aviation Accidents in Slovakia through HFACS Framework: A Comprehensive Study. *Transportation Research Procedia. Volume 75*, 2023. https://doi.org/10.1016/j.trpro.2023.12.020
13. *Manual on Human Performance for Regulators* (Doc 10151) First Edition (ICAO, Montreal).
14. Muecklich, N., Sikora, I., Paraskevas, A., & Padhra, A. (2023), The role of human factors in aviation ground operation-related accidents/incidents: A human error analysis approach. *Transportation Engineering. Volume 13*, 2023. https://doi.org/10.1016/j.treng.2023.100184
15. MTBiGM – PKBWL (2011). *Raport Końcowy. Wypadek, Zdarzenie Nr – 835/2011, Statek Powietrzny – samolot ATR-72, SP-LFH, Data i Miejsce Zdarzenia – 14 lipca 2011 r.* Ministerstwo Transportu, Budownictwa i Gospodarki Morskiej – Państwowa Komisja Badania Wypadków Lotniczych. https://asn.flightsafety.org/reports/2011/20110714_AT72_SP-LFH.pdf
16. SKYbrary. (2025, March 28th). *Aircraft Ground Damage*. https://skybrary.aero/articles/aircraft-ground-damage
17. Sofema Aviation Services. (2025, March 30th). *Aircraft Apron & Ramp Safety and Human Factors Training Essentials – 1 Day*. https://sassofia.com/course/aircraft-apron-ramp-safety-human-factors-training-essentials-1-day/
18. TVN24. (2024, June 27th). *Kolizja dreamlinera z pomostem pasażerskim na lotnisku*. https://tvn24.pl/tvnwarszawa/wlochy/kolizja-dreamlinera-z-pomostem-pasazerskim-na-lotnisku-chopina-st7982050