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An HFACS-Based Analysis of Occupational Accidents in Aircraft Ground Handling: A Multi-Station Case Study (2023–2025)

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Abstract

Objective

Aircraft ground handling is labour-intensive, with staff, equipment and aircraft sharing confined apron space. This descriptive case study profiles occupational accidents at a multi-station ground handling company (2023–2025) by time, location and operation, and analyses their underlying factors with the Human Factors Analysis and Classification System (HFACS). With no exposure denominator available, results are raw counts, not incidence rates.

Methods

This retrospective, records-based study used mixed methods. We summarised 1,930 accident records from 32 stations with descriptive and inferential statistics, and coded the free-text root-cause fields by rule-based content analysis across the four HFACS levels: unsafe acts, preconditions, unsafe supervision and organisational influences.

Results

Records rose from 424 in 2023 to 881 in 2025, and two large stations accounted for 71.2% of events. Loading, below-the-wing and unloading made up 43.0% of accidents; the apron was the commonest location, with a summer peak. Some 5,369 workdays were lost, and 33 events exceeded 30 sick-leave days. Preconditions dominated the HFACS layers (62.4%; mainly ergonomic strain and the physical environment), ahead of organisational influences (23.0%) and unsafe supervision (0.8%). Preconditions led in every phase (chi-square = 43.4; $p < 0.001$).

Conclusion

Risk concentrates on the apron and in manual load handling, though terminal and support areas also contribute. Root-cause records stay at the individual, immediate level, with supervisory and organisational factors seldom recorded. The findings favour a prevention strategy built on ergonomics and organisational safety rather than a “blame-and-train” approach.

Keywords: ground handling safety, HFACS, aviation occupational injury, ergonomics, human factors, safety culture

1. Introduction

The turnaround between an aircraft’s arrival and its next departure is short. Within this narrow window, many tasks are performed largely by hand: marshalling, loading and unloading baggage and cargo, passenger services, cabin cleaning and pushback. Together these tasks make up aircraft ground handling. They place numerous ground service equipment (GSE) units and staff in the same confined space under time pressure, which makes the apron a high-risk setting for occupational accidents. International estimates indicate that apron accidents and incidents impose a serious human and economic burden worldwide (Flight Safety Foundation, 2003; ACRP, 2010).

Early epidemiological studies of ground crew injuries found that risk is highest during aircraft arrival, departure and the pre-departure phases (Grabowski, Baker & Li, 2005; Ribak, Cline & Froom, 1995). Most of these studies draw on national accident databases and focus on fatal or severe events. Few examine the multi-station, non-fatal accident records of a single company at the level of the operational phase. Regulatory reports likewise note the absence of comprehensive, standardised injury data for the ramp (U.S. GAO, 2007).

2. Literature Review

Treating accident causation purely as “human error” is inconsistent with modern safety management. The Human Factors Analysis and Classification System (HFACS), grounded in Reason’s (1990) distinction between latent and active failures, examines causes across four layers: unsafe acts, preconditions for those acts, unsafe supervision and organisational influences (Wiegmann & Shappell, 2003; Shappell & Wiegmann, 2000). In a review of 43 studies, Hulme et al. (2019) found HFACS to be one of the most widely used accident analysis methods in human factors and ergonomics, with applications in aviation, maritime, rail, mining, construction and healthcare. The framework was first developed and validated in military and civil aviation (Shappell et al., 2007; Wiegmann & Shappell, 2001) and later adapted to other sectors. An HFACS-RA model was built for railways (Zhan, Zheng & Zhao, 2017; Reinach & Viale, 2006); the paths between latent and active errors were examined in Chinese rail accidents (Zhou & Lei, 2018); the method was applied to coal-mine accidents (Zhang et al., 2019; Patterson & Shappell, 2010; Lenné et al., 2012); HFACS-MA was derived for maritime use (Chen et al., 2013; Çelik & Çebi, 2009; Chauvin et al., 2013; Akyuz & Celik, 2014); HFACS-OGI was proposed for oil and gas (Theophilus et al., 2017); and the framework was carried into healthcare (Diller et al., 2014). These adaptations share a common feature: they retain the four original layers and add sector-specific subcategories or an external regulatory layer. Many such studies code the free-text content of accident reports into pre-defined categories, and rule-based or semi-automated classification of free text is increasingly common in the safety literature (Hughes et al., 2018). Methodological work on incident coding stresses that inter-coder agreement and the coding protocol should be reported transparently (Olsen, 2013). HFACS has recently been applied to ground operations; Muecklich et al. (2023), for example, analysed 87 incident reports that mostly involved aircraft or equipment damage. Yet few studies apply the framework to the multi-station, phase-level, worker-injury records of a single company. By focusing on worker-injury records rather than incident reports, and on descriptive analysis at the level of raw frequency, the present study addresses this gap.

Interest in the health and safety of ground handling staff has grown in recent years. Baggage and load handlers carry a high risk of musculoskeletal disorders (MSDs) from heavy lifting, awkward postures, repetitive movement and work in confined spaces, with the lower back and shoulders most affected (Reddell et al., 1992; Tafazzol et al., 2016; Bergsten et al., 2015). Cohort studies of baggage handlers at Copenhagen Airport linked the cumulative time spent handling baggage to the risk of hospital admission for low-back problems, subacromial shoulder disorder and knee osteoarthritis (Thygesen et al., 2016; Brauer et al., 2020; Mikkelsen et al., 2019; Møller et al., 2018). The risk is not only physical. Organisational and psychosocial factors also contribute: job satisfaction, leadership quality and work organisation are associated with MSD severity (Bergsten et al., 2015; Bulduk et al., 2017; Da Costa & Vieira, 2010). Shift work and fatigue further raise accident risk among ramp staff (Santos & Melicio, 2023). In recent studies that coded ground operation reports with HFACS and related frameworks, poor situational awareness and failure to follow procedures emerged as the main contributing factors (Muecklich et al., 2023). On prevention, there is evidence that mechanical lift aids such as vacuum lifters and conveyors reduce the spinal load of handling (Dell, 1998). In Turkey, ground handling occupational health and safety has been studied mainly through risk assessment, training and surveys; empirical analyses based on real, multi-station accident records remain scarce.

This case study has two aims: (i) to describe the profile of three years of occupational accidents in a multi-station ground handling company across temporal, spatial, operational and severity dimensions; and (ii) to analyse the causal structure of those accidents with HFACS and to generate hypotheses about prevention priorities. No exposure denominator was available, so incidence rates are not calculated and stations are not ranked by risk. The study makes two contributions. It applies HFACS-based content analysis to non-fatal corporate accident records broken down by operational phase; and it reads the structure of those records as a signal of the organisation's safety-culture maturity, linking field-level injury patterns to organisational safety and learning.

3. Materials and Methods

3.1 Study Design

This is a retrospective, records-based mixed-methods study. It combines a quantitative descriptive analysis with a qualitative content analysis. The quantitative component covers the temporal, spatial, operational and severity dimensions of the accidents; the qualitative component covers their causal structure within the HFACS framework.

3.2 Data Source and Study Population

The data come from the corporate incident and accident reporting system of a ground handling company and cover 2023–2025. Each record contains the accident number, date and time, record type, a short event description, the station, the operational phase, the effect (severity), the location, the root cause, the planned and completed actions, and the lost workdays (sick-leave days). After full calendar years were ensured, the study population comprised 1,930 occupational accident records from 32 stations. The case definition follows the company's reporting practice. Every event a worker experiences on duty is recorded under the type "Occupational Accident", from minor cases where the worker receives first aid and returns to work to severe cases ending in sick leave. The reporting threshold is low, so both minor and severe events appear in the same data set.

This breadth should be kept in mind when interpreting the severity distribution, such as the sick-leave rate.

3.3 Data Preparation and Variables

The raw data contained 1,932 records. Two records from 2026 were removed to retain complete calendar years. Year, month, day and hour were derived from the date-time field. Lost workdays were treated as a continuous (day) variable. Operational phase and location were kept at the level of the corporate coding.

3.4 HFACS Coding Protocol

The free-text root-cause and event-description fields were coded using the four HFACS layers and their operational subcategories (Table 1). The subcategories adapted to ground handling are: skill-based error and decision error (unsafe acts); adverse mental or physical state, physical/technical environment, ergonomic strain and equipment/GSE condition (preconditions); inadequate supervision (unsafe supervision); and training/communication and workforce/process planning (organisational influences).

Coding used a **rule-based (dictionary-based) content analysis**. For each subcategory, a set of key terms was defined in advance. The dictionary was built from recurring phrases in the accident records — for example, “loss of balance/attention”, “rushing”, “heavy lifting”, “slippery surface” and “faulty conveyor” — and mapped to each subcategory. Because one event can implicate more than one layer, overlapping coding was used, so the layer percentages sum to more than 100%. Rule-based and semi-automated classification of free-text reports into a pre-defined framework is established in rail and other safety studies (Hughes et al., 2018; Zhou & Lei, 2018). The method has a clear limitation: dictionary matching is less sensitive to context than human coding and may not fully capture latent organisational or supervisory factors. This is addressed openly in the Results and Discussion when the low share of the supervisory layer is interpreted.

Coding reliability was assessed by re-coding a random subsample of 200 records by hand. A second coder, blind to the dictionary output, performed this coding, and inter-coder agreement was computed per layer with Cohen’s kappa. Pooled agreement across all layers was moderate at $\kappa = 0.45$ (overall agreement 79.5%) (Landis & Koch, 1977). By layer, agreement was $\kappa = 0.44$ for unsafe acts and $\kappa = 0.50$ for unsafe supervision, but only $\kappa = 0.15$ for organisational influences. This shows how difficult it is to code latent organisational factors consistently from free text, and it supports a cautious reading of the low share of the supervisory and organisational layers.

Coverage was checked across the full data set. 79.5% of records matched at least one HFACS layer; 20.5% could not be assigned to any layer with the current dictionary (mean 1.14 layers per event; 29.9% of events were multi-layer). Unmatched records were mostly those with an empty root-cause field, or those describing only the outcome of the event with no causal content. Given the limited contextual sensitivity of dictionary coding, the inferences are read at the level of the relative frequency of layers, not as a single causal attribution per event.

Table 1. The HFACS coding framework used in the study (adapted to ground handling).

HFACS layer	Subcategory (example)	Example indicator from ground handling
Unsafe acts	Skill-based error; decision error; violation	Loss of balance/attention; wrong technique; not using PPE
Preconditions	Adverse state; environment; ergonomics; equipment/GSE	Rushing/fatigue; slippery surface/wind; heavy lifting; faulty conveyor
Unsafe supervision	Inadequate oversight/supervision	Lack of supervision/control during the operation
Organisational influences	Training/communication; workforce/process planning	Training/orientation gaps; workload and shift planning

3.5 Statistical Analysis

Variables were summarised with frequency, percentage, mean, median and range. Because lost workdays had a right-skewed, zero-heavy distribution, central tendency is reported with both the mean and the median. The chi-square goodness-of-fit test assessed whether categorical distributions departed from a uniform expectation. The chi-square test of independence assessed the relationship between two categorical variables, with effect size reported as Cramér's V. For temporal distributions (month, weekday), expected frequencies were adjusted for the number of calendar days in the period. The yearly count trend was assessed by linear regression. Lost workdays (continuous and skewed) were compared across groups with the non-parametric Kruskal–Wallis and Mann–Whitney U tests. The significance level was $p < 0.05$. Analyses were run in Python (SciPy), and the findings are presented in tables and figures.

3.6 Ethics

The study rests solely on retrospective analysis of corporate records. Personal identifiers were removed, and the analysis was conducted at the event level, not the individual level.

3.7 Limitations

The main limitation is the absence of an exposure denominator (flights or turnarounds, worker-hours or passenger volume). Comparisons across stations and years are therefore reported as raw frequencies rather than incidence rates, and the differences observed may reflect operation volume and reporting culture as much as real differences in risk. Second, because the HFACS coding is based on free text, the low share of the supervisory and organisational layers may not indicate genuine scarcity but rather that the corporate root-cause records document these layers poorly. Third, the data come from a single company, so the findings have limited generalisability and should be read as a case analysis. Fourth, the data include only occupational accidents that occurred and were reported. Near-misses, unreported minor injuries and occupational diseases fall outside the scope. The findings thus capture only the reported and realised portion of total risk and may understate the true accident burden. Fifth, the analysis applied a battery of significance tests without correction for multiple comparisons, so individual p-values should be read as descriptive rather than confirmatory; the yearly linear trend in particular rests on only three annual points, and the goodness-of-fit tests establish only that events depart from a uniform distribution, not why.

4. Results

Over the study period, 1,930 occupational accident records were obtained from 32 stations. All were classified in the corporate system as "Occupational Accident".

4.1 Temporal Patterns

The yearly number of records rose steadily across the study period (Figure 1). As noted under Limitations, this trend should be read alongside growth in operation volume and improvements in reporting culture.

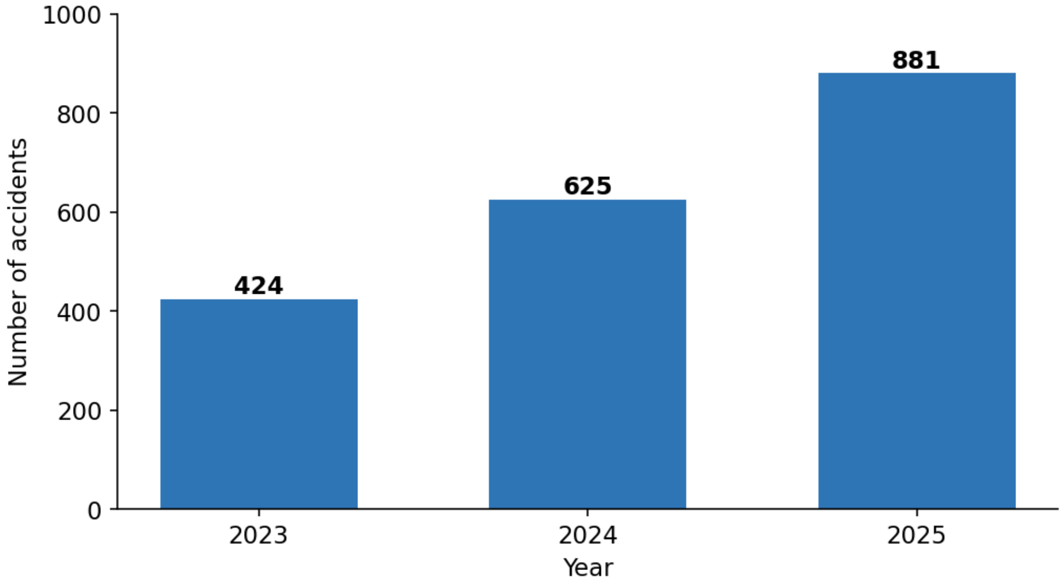

Figure 1. Number of occupational accidents by year (2023–2025).

The monthly distribution showed clear seasonality (Figure 2): events peaked in summer and reached their highest level in July, consistent with the heavy flight traffic of the summer tourism season. By hour, there was a pronounced midday peak and a secondary clustering in the evening and night shifts (Figure 3), likely linked to busy operating windows and shift changes.

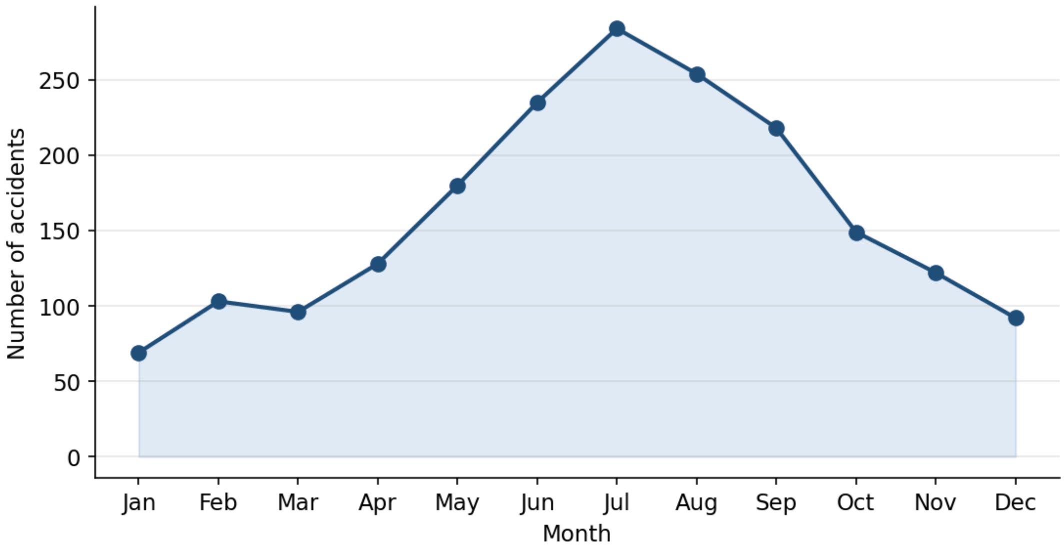

Figure 2. Distribution by month (seasonality).

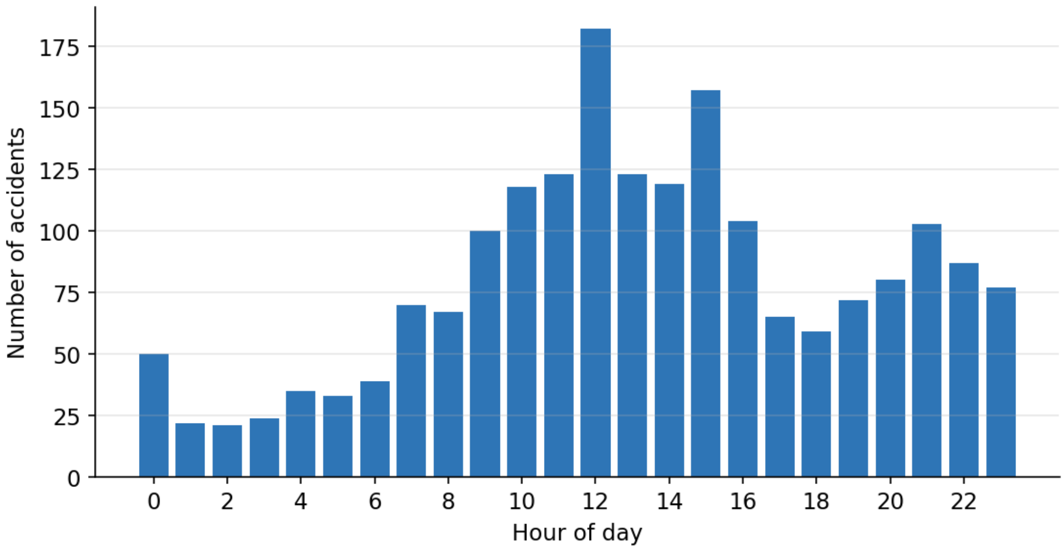

Figure 3. Distribution by hour of day.

4.2 Spatial and Station-Level Patterns

Records were unevenly distributed across stations (Figure 4). Two large stations, AYT and IST, together held 71.2% of all records. Without an exposure denominator this concentration cannot be read as a difference in risk; it reflects the number of events, most likely driven by the operation volume of these two stations. Comparing their monthly patterns, AYT showed clear summer clustering while IST was fairly even across the year (Figure 5) — a difference in traffic profile rather than risk. By location, the largest share fell in the aircraft parking area (apron), followed by the aircraft hold and cargo area and the below-the-wing area.

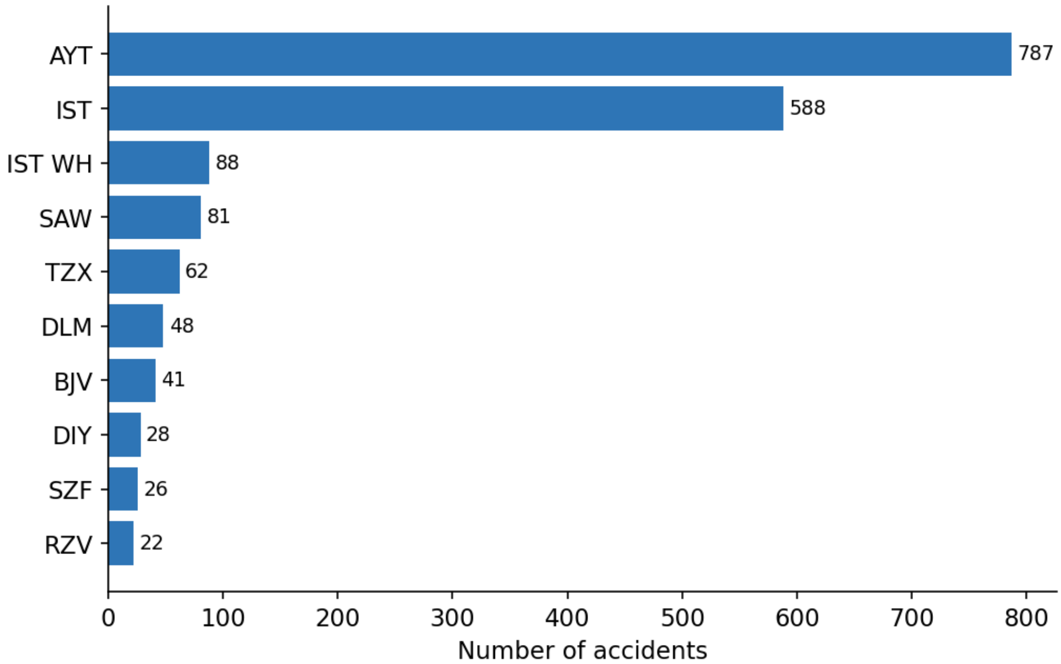

Figure 4. Distribution by station (top 10 stations).

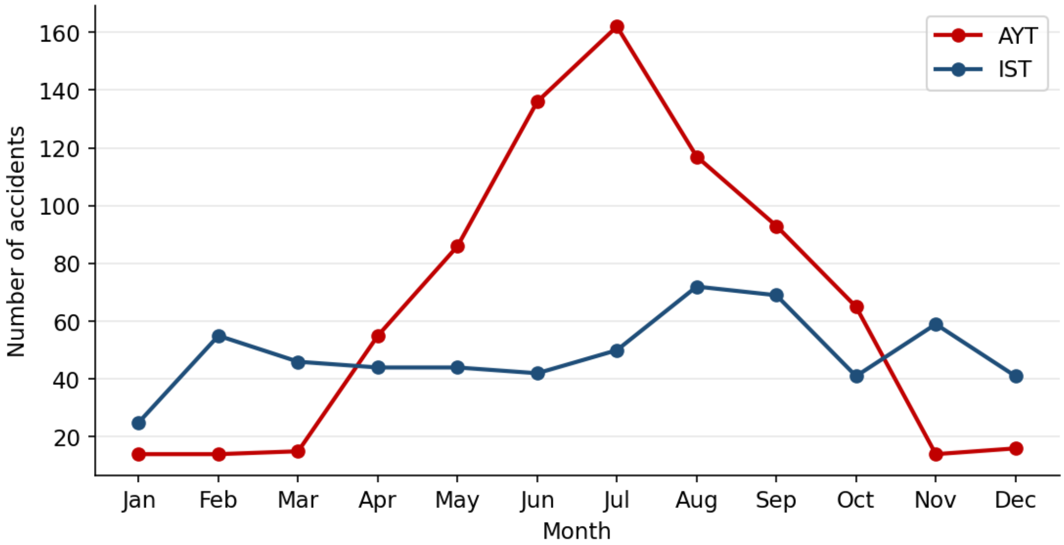

Figure 5. Monthly distribution at AYT and IST stations.

4.3 Operational Phase

By operational phase, loading was the most frequent, followed by below-the-wing operations and unloading (Figure 6). Together, these three manual load-handling phases accounted for 43.0% of all accidents.

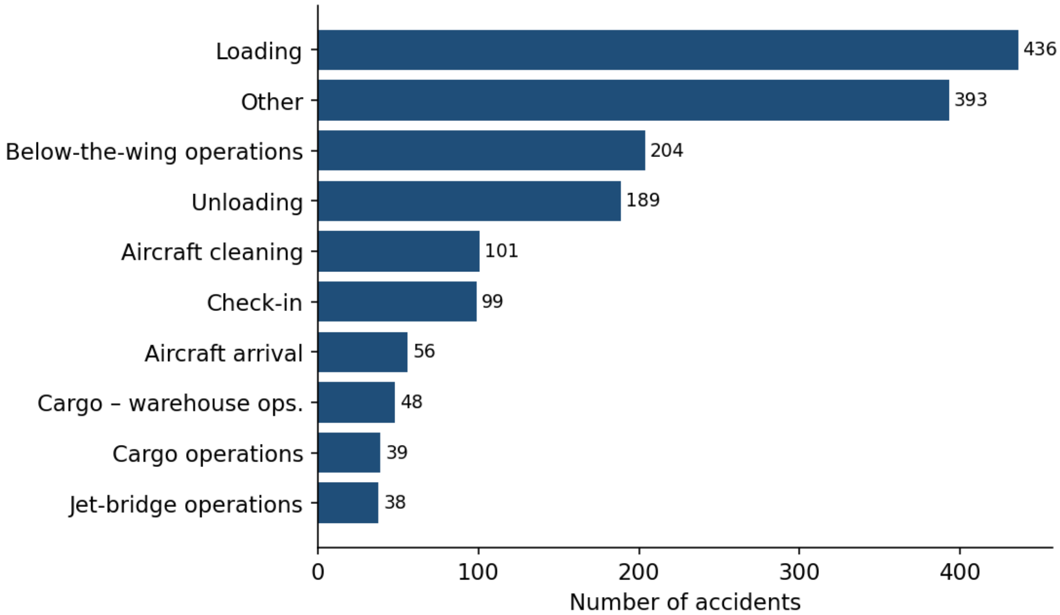

Figure 6. Distribution by operational phase (top 10 phases).

4.4 Accident Severity and Lost Workdays

By effect, the largest group comprised events requiring treatment and sick leave, followed by minor events where the worker received first aid and returned to work (Figure 7). In total, 806 events (≈42%) led to at least one day of sick leave, and 5,369 workdays were lost. The distribution of sick-leave days was strongly right-skewed: the median was zero days, the mean for sick-leave events was 6.7 days, and the longest single absence was 159 days. In all, 140 events led to ≥10 days and 33 events to ≥30 days of sick leave (Table 2). This heavy tail shows that a small number of serious events account for most lost workdays.

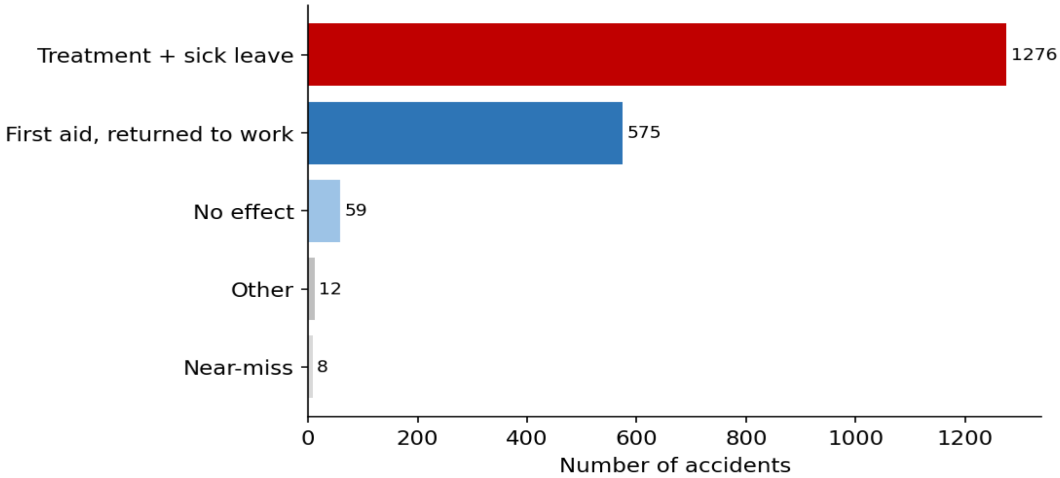

Figure 7. Distribution by accident effect (severity).

Table 2. Summary statistics for lost workdays (sick leave).

Indicator	Value
Events resulting in sick leave	806 (≈42%)
Total lost workdays	5,369 days
Mean duration for sick-leave events	6.7 days
Median sick-leave duration (all events)	0 days
Events with ≥10 days of sick leave	140
Events with ≥30 days of sick leave	33
Longest single sick leave	159 days

4.5 HFACS Causal Analysis

Among the coded events, 79.5% matched at least one causal layer. The leading layer was preconditions for unsafe acts, present in 62.4% of events, followed by unsafe acts (28.2%) and organisational influences (23.0%). Unsafe supervision was coded in only 0.8% (Figure 8). Because an event can implicate several layers, these percentages overlap and do not sum to 100%.

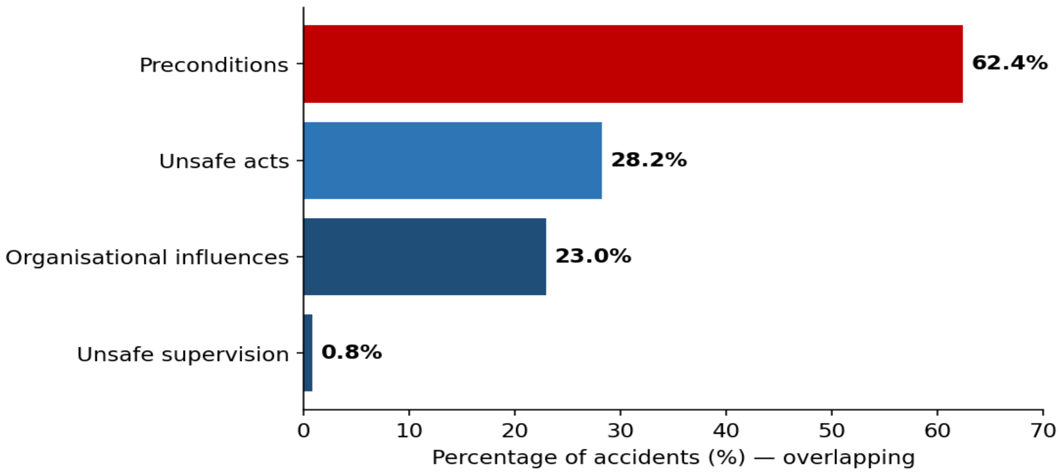

Figure 8. Distribution of HFACS causal layers (overlapping).

At the subcategory level, the most frequent factor was ergonomic strain and job design (30.3%), followed by skill-based error (21.7%), equipment/GSE condition (21.3%), physical/technical environment (20.2%) and workforce/process planning (19.6%) (Figure 9). Training and communication gaps (3.6%) and inadequate supervision (0.8%) were clearly under-represented.

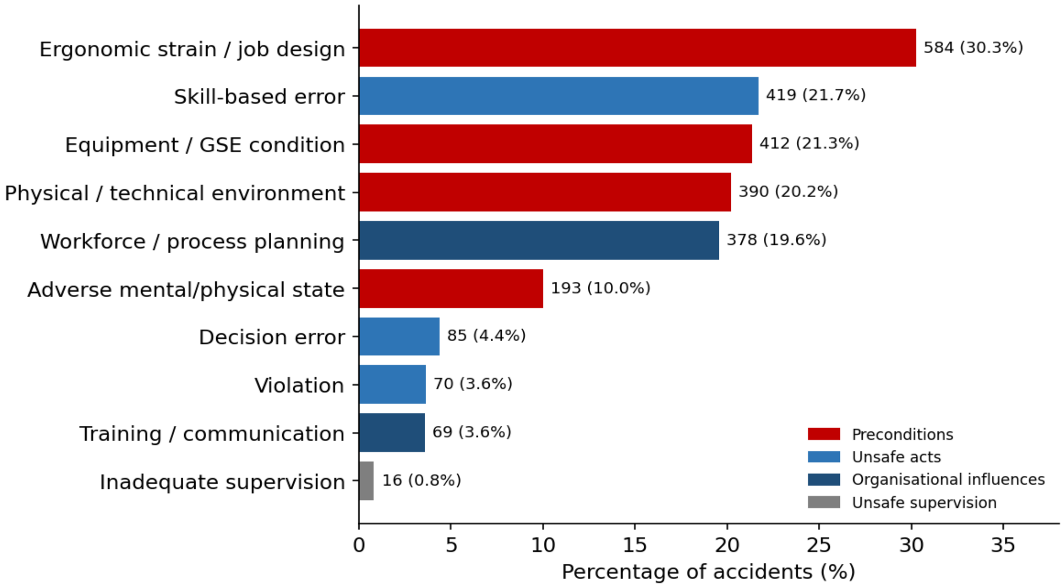

Figure 9. Distribution of HFACS subcategories (overlapping).

Broken down by operational phase, preconditions for unsafe acts led in every phase (Figure 10), reaching their highest shares in unloading (72.0%), check-in (72.7%) and loading (70.0%) and their lowest in the "other" phases (55.4%). The distribution of preconditions across phases was significant (chi-square = 43.4; df = 5; p < 0.001), and unsafe supervision never exceeded 1.5% in any phase. Preconditions linked to ergonomic strain and the physical environment are thus not specific to a single phase; they run systemically through ground handling processes.

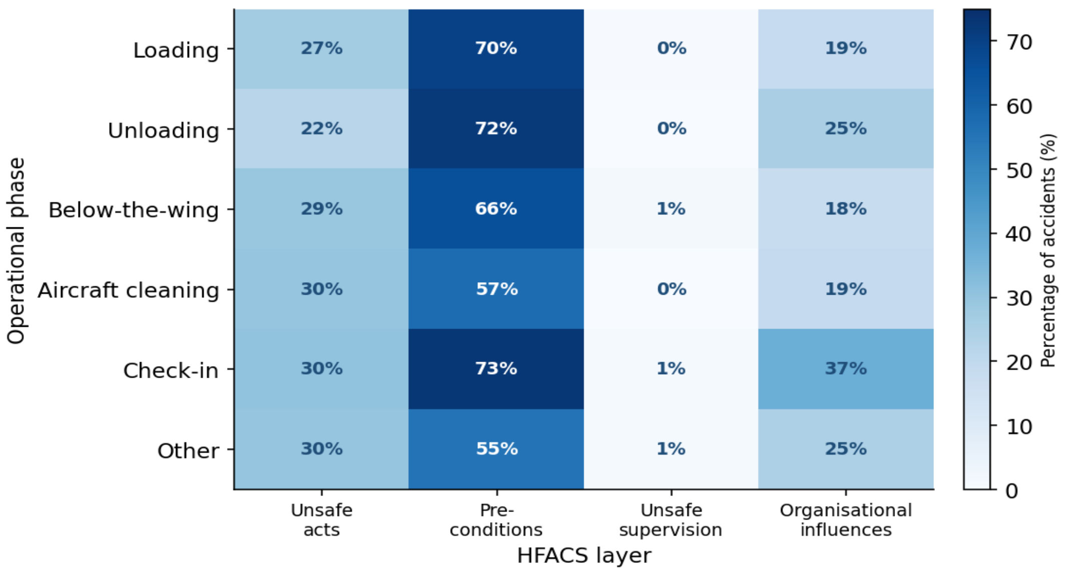

Figure 10. Distribution of HFACS causal layers by operational phase (each cell shows the percentage of events in that phase coded to the layer).

4.6 Inferential Analyses

The descriptive patterns were confirmed with the relevant tests (Table 3). The yearly number of records differed significantly from a uniform distribution (chi-square goodness-of-fit = 163.1; $p < 0.001$) and followed an upward linear trend ($R^2 = 0.995$), though this trend rests on only three annual points and is reported for description only. The monthly distribution showed significant seasonality against the day-adjusted expectation (chi-square = 343.4; df = 11; $p < 0.001$), with the busiest month (July) running about 4.1 times the lowest (January). The distribution by shift block was also significantly clustered (chi-square = 205.1; df = 2; $p < 0.001$), whereas weekdays did not differ significantly (chi-square = 11.8; df = 6; $p = 0.067$).

Lost workdays were significantly related to operational phase (chi-square = 35.5; df = 5; $p < 0.001$), though the effect size was weak to moderate (Cramér's V = 0.14). The highest sick-leave rates were in below-the-wing (51.0%), unloading (49.7%) and loading (47.0%). Compared as a continuous value across phases, lost workdays again differed significantly (Kruskal–Wallis H = 28.5; $p < 0.001$), but with a zero median in most phases the practical difference is small. This is consistent with the heavy-tail finding that severity comes from a few serious events. Events coded with HFACS preconditions showed somewhat higher lost workdays than those without (Mann–Whitney U; $p = 0.014$).

The clearest inferential finding concerns the trend in severity over time. Although accidents rose from 2023 to 2025, the share leading to sick leave fell from 50.2% in 2024 to 33.0% in 2025 (year × sick leave chi-square = 51.6; $p < 0.001$) (Figure 11). A rising count alongside a falling share of severe events can be interpreted in several ways. One is that the rise comes mainly from more minor events being reported under a lower threshold, consistent with a maturing reporting culture. Without a denominator, however, this cannot be tested directly, and other explanations are equally plausible: growth in operation volume, higher staff turnover and a larger share of inexperienced or seasonal workers, or administrative changes in recording. The raw yearly count alone should therefore not be read as a deterioration in safety, but the dominant mechanism cannot be identified from these data.

Table 3. Summary of the inferential analyses.

Analysis	Test	Statistic	df	p	Comment
Yearly distribution (equal expectation)	Chi-square GoF	163.1	2	<0.001	Years differ significantly
Yearly trend (count)	Linear regression	R^2=0.995	—	0.044	Strong upward trend
Seasonality (monthly)	Chi-square (day-adj.)	343.4	11	<0.001	Clear summer peak (4.1×)
Weekday	Chi-square (day-adj.)	11.8	6	0.067	No significant difference
Shift block	Chi-square	205.1	2	<0.001	Day/evening clustering
Sick leave (yes/no) × phase	Chi-square	35.5	5	<0.001	Cramér's V=0.14 (weak–mod.)

Analysis	Test	Statistic	df	p	Comment
Lost workdays × phase	Kruskal–Wallis	H=28.5	5	<0.001	Significant; small effect
Lost workdays × precondition	Mann–Whitney U	—	—	0.014	Slightly higher with precond.
Sick-leave rate × year	Chi-square	51.6	2	<0.001	Rate drop in 2025 (33%)

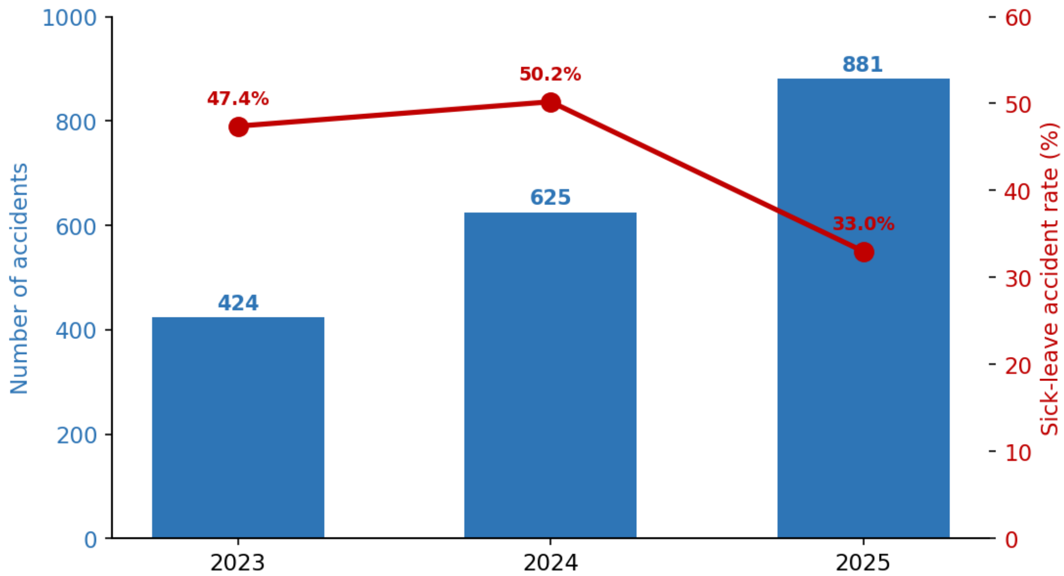

Figure 11. Number of accidents per year and the sick-leave accident rate.

5. Discussion

This study analysed three years of occupational accidents in a multi-station ground handling company, both descriptively and through HFACS-based causal analysis, identifying where risk concentrates and the structure of the factors behind it. The concentration on the apron and in manual load handling matches the literature, which shows that ground crew injuries cluster in phases close to the aircraft (Grabowski et al., 2005). Here a conceptual distinction matters. Most ground handling safety research concerns aircraft and equipment damage (ground damage) and ramp safety (ACRP, 2010; Flight Safety Foundation, 2003), whereas the present data concern worker injuries. These belong to two distinct domains — the aviation safety management system on one hand and occupational health and safety on the other — and cannot be compared directly. Only part of the accident locations lay on the apron; off-apron areas such as the counter, office, warehouse, workshop and cafeteria also took a notable share. Ground handling occupational health and safety cannot, therefore, be reduced to apron safety; a whole-system approach covering terminal and support processes is required. Even so, the apron being the most frequent location, and loading, below-the-wing and unloading the most frequent phases, confirms that apron safety and load-handling ergonomics are priorities for action.

Set against the international literature, the findings show both overlaps and differences. Muecklich et al. (2023), analysing 87 ground operation accident reports with HFACS and human factors frameworks, identified poor situational awareness and failure to follow procedures as the main contributing factors. Here, the prominent factors lay at the precondition level, such as ergonomic strain and the physical environment. The difference stems partly from the data source: those studies rely mostly on aircraft and equipment damage reports, whereas this study covers worker injuries, in which preconditions linked to musculoskeletal load and handling are expected to dominate. Both approaches nonetheless converge on a key point: accidents arise largely from human and organisational factors, with technical or mechanical failure secondary. Evidence of high MSD rates among ground handling staff, driven by both physical and organisational-psychosocial factors (Bergsten et al., 2015), supports the ergonomics-focused findings reported here.

The most striking HFACS finding is the dominance of the precondition layer — especially ergonomic strain and the physical environment — against the low share of the unsafe supervision and organisational layers. Two readings are possible. The first is that accidents are genuinely driven by immediate, ergonomic factors. The second, and more likely, is that the corporate root-cause records remain at the individual and immediate level and do not systematically document latent organisational and supervisory factors. The safety literature treats this as the limitation of the "blame-and-train" approach: ramp incidents often stem from latent system failures that cannot be resolved at the operator level alone (ACRP, 2010; Ek & Akselsson, 2007). Reason's (1990) framework requires attention to the organisational conditions behind visible unsafe acts.

The near-absence of the supervisory and organisational layers is also telling in terms of just culture. In aviation safety management, a just culture interrogates systemic conditions rather than blaming the individual; unintended errors are not punished, which encourages open and honest reporting (Reason, 1997; Dekker, 2007). Root-cause records that rest on immediate causes such as individual "carelessness" and "rushing" suggest that the company's incident investigation has not yet reached just-culture maturity.

The pattern also fits a wider frame of safety culture and organisational learning. Reason's (2000) systems approach holds that accidents are products of organisational conditions more than individual faults, so investigation should target the system rather than the person. Rasmussen's (1997) dynamic socio-technical view likewise locates safety performance not only at the operator level but in the interaction of managerial and regulatory layers. Safety culture maturity models (Hudson, 2003; Patankar & Sabin, 2010) suggest that, as an organisation moves from a reactive or blaming stage to a generative, learning one, its investigations begin to document more latent and organisational factors. The near-absence of these layers here may therefore indicate an early position on that maturity axis. Accident reports in other high-risk sectors have similarly been shown to under-document organisational factors (Schröder-Hinrichs et al., 2011). It has also been argued that safety culture alone cannot explain accident causation and must be paired with systems thinking (Reiman & Rollenhagen, 2014). The labour-intensive, time-pressured character of ground handling (Kazda & Caves, 2015) is one structural barrier to such maturity.

This frame also informs the rise in yearly accident counts (Section 4.1). The International Civil Aviation Organization's safety management system (SMS) approach holds that, in a maturing reporting culture, a rise in reported events — particularly low-severity ones — is expected and positive (ICAO, 2018). The parallel fall in the severe share (Section 4.6.) fits this reading.

The summer clustering, and especially the sharp seasonal swing at AYT, suggests that event numbers rose with traffic volume, since turnarounds peak at these stations during the summer tourism season. Even without a denominator to separate a real rise in risk from higher volume, the absolute rise in summer — combined with seasonal staffing, shorter training time and fatigue — makes pre-season training and capacity planning a practical priority.

The right-skewed lost-workday distribution calls for a two-pronged prevention strategy: the high-frequency minor events (pinching, striking) and the low-frequency but serious events that lead to long sick leave must be addressed separately. Despite being a single-company case study, the work draws on a detailed, event-level data set spanning three years and 32 stations, includes a breakdown by operational phase, and applies a systematic causal framework in HFACS. Future studies should add an exposure denominator to calculate incidence rates, link the HFACS coding to multivariable models such as negative binomial regression, and extend the coding with a full-sample, multi-coder reliability analysis.

6. Conclusion and Recommendations

The three-year data show that occupational accident risk in ground handling concentrates around the apron, manual load handling and heavy summer traffic. The HFACS analysis shows the dominance of ergonomic preconditions and the under-representation of organisational and supervisory layers in the records. In light of these findings, the priority recommendations are as follows:

- Conduct ergonomic risk assessments for the loading, unloading and below-the-wing processes, and make mechanical load-handling aids more widely available.
- Strengthen apron safety: review the rules for GSE positioning, visibility and the separation of pedestrians and vehicles.
- Base root-cause analysis on a systematic framework such as HFACS, and deliberately interrogate the supervisory and organisational layers.
- Establish intensive pre-season training, mentoring and orientation for seasonal and new staff as a permanent practice.
- Create a separate in-depth investigation and prevention programme for serious events involving long sick leave.
- Monitor accident data together with an exposure denominator (turnarounds or worker-hours) and move to incidence-rate-based safety performance indicators.

Declarations

Conflict of Interest. The authors declare no conflict of interest.

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