The role of human factors in aviation ground operation-related accidents/incidents: a human error analysis approach

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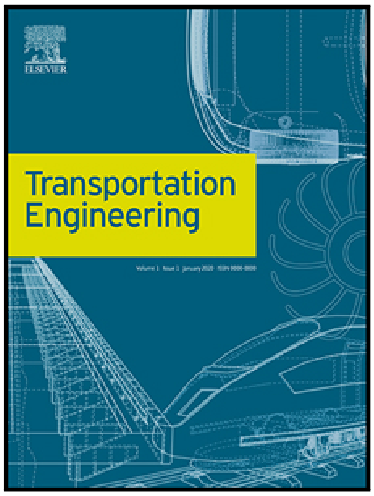

The Role of Human Factors in Aviation Ground Operation-related Accidents/Incidents: A Human Error Analysis Approach

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Highlights

- Content analysis of 87 aviation accident reports with Ground Operations contributing factors
- Two well established accident models provided the basis for the in-depth template analysis
- Identification and discussion of ten emerging human error themes in aviation Ground Operations
- Directions for future research to address main accident causal and contributing factors

Title Page

Name of the Article

The Role of Human Factors in Aviation Ground Operation-related Accidents/Incidents: A Human Error Analysis Approach

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ABSTRACT

Aviation is a complex socio-technical system with interconnected and interdependent subsystems, such as flight operations, air traffic control, aircraft maintenance and ground operations. However, safety and risk research has not paid, thus far, adequate attention to all subsystems, resulting in possibly undetected or underestimated risks. This study focuses on Ground Operations (GO) as a subsystem and analyses the role of human factors in ground operations related accidents and incidents. 87 accident and incident reports (from 2000 to 2020) were analysed in three stages, using the Human Factors Dirty Dozen (HF DD) Model and the Human Factors Analysis and Classification Scheme (HFACS) as a basis for the third stage, a systematic thematic analysis. The findings indicate that lack of situational awareness and failure to follow prescribed procedures are the main causal and contributing factors in GO-related accidents and incidents. Three operational actions were identified as most critical: aircraft pushback/towing, aircraft arrival and departure, and aircraft weight and balance. An agenda for future research and recommendations for industry corrective action are proposed.

KEYWORDS

Aviation

Aircraft Accident Analysis

Ground Operations

Human Factors Analysis and Classification Scheme

Thematic analysis

Content analysis

1. INTRODUCTION

The aviation system is a complex socio-technical system consisting of different subsystems, such as flight operations, ground operations, aircraft maintenance, or air traffic management. Each of these subsystems fulfils its part to enable the safe and efficient_operation of passenger and cargo flights around the world (Rodrigues, 2021; Das and Dey, 2016).

Technological progress and advances in training, standards, and procedures, have increased flight safety to unprecedented levels (Sikora, 2015; Stolzer and Goglia, 2015). The number of accidents, and especially of fatal accidents, has been staggeringly reduced in the last 60 years, from 40 fatal accidents per 1 million flights in 1959 to approximately 0.14 fatal accidents per 1 million flights on a five-year average of 2017-2021. (Allianz, 2014; IATA 2022). Nevertheless, accidents still happen and new challenges continuously arise.

When investigating accidents and incidents in aviation, the focus is usually placed on the operational subsystems with the most central or visible role, sometimes_defined as primary subsystems, such as the cockpit crew flying the aircraft or air traffic control (ATC) managing the airspace (Jakšić and Janić, 2020; Karanikas and Nederend, 2018; Fraher, 2015). However, secondary operational subsystems also play a role in ensuring the safety, efficiency, and effectiveness of flights. In the context of this study, we define as secondary subsystems the less visible ones, such as ground operations (ground crew loading, unloading, and servicing the aircraft), and aircraft maintenance (personnel conducting the scheduled and unscheduled aircraft maintenance, repair, and overhaul) (Guo *et al.*, 2021; Herrera and Hovden, 2008). In this study we focus our analysis on the secondary subsystem Ground Operations.

The contribution of secondary subsystems to accidents and incidents appears to be less studied, even though safety failures in these can lead to overall_system disruptions delays, damages to the aircraft or equipment and injuries of people (Evler et al.,2021; NTSB, 2015; Wu and Caves, 2003). To address this gap, this study aims to explore the role of human factors in aviation Ground Operation-related accidents and incidents in by analysing accident reports between 2000 and 2020 using the Human Factors Dirty Dozen (HF DD) model (Dupont, 1997), the Human Factors Analysis and Classification Scheme (HFACS) (Shappell & Wiegmann, 2001) as analytical frameworks, and a systematic thematic content analysis.

Human error in aviation

Human error has been identified as the number one causal and contributing factor to aviation accidents and incidents. Dependent on the source, up to 80% of aviation accidents and incidents identify human error as a causal or at least contributing factor (Shappell et al., 2007, McFadden & Towell, 1999, Kelly & Efthymiou, 2019, Khan et. al., 2022). Therefore, the analysis of potential human error preconditions is a key component in applying the systems view on aviation safety (Reason, 2000; Shappell and Wiegmann, 2001).

Human error management approaches in aviation address the characteristics of the different high-risk subsystems with adapted management and training approaches. These approaches aim in preventing accidents and incidents within the system caused by errors of human factors, thus limiting risks, and improving safety in the operation and its processes (Reason, 1997, 2000; Wiegmann and Shappell, 2001; Helmreich, 2000).

There are different approaches in analysing human error – the main human factor in accidents and incidents - (Cacciabue, 2004; Kirwan, 1998, Rasmussen et. al., 1990). TRACEr, for example, is a technique for the retrospective and predictive analysis of cognitive errors in ATC (Shorrock and Kirwan, 2002). Other approaches employed in aviation are the Human Factors Dirty Dozen (HF DD) model (Dupont, 1997; Kim et al., 2020; Miller and Mrusek, 2019; Yilmaz, 2019) and the more advanced Human Factors Analysis and Classification Scheme (HFACS) (Gaur, 2005; Li et al., 2008; Shappell et al., 2007).

We use the **Human Factors Dirty Dozen (HF DD)** model - as a starting point to identify the preconditions for human error in aviation accidents or incidents. The model lists twelve dominant preconditions for human error in an operation or in a system that can lead to or are precursors to accidents or incidents (Figure 1). The HF DD is neither a holistic, nor a comprehensive list of precursors. Nevertheless, the model has been widely used to identify human error factors in accident analysis in aviation as well as in health care (Nzelu et. al., 2018; Samad et al, 2018).

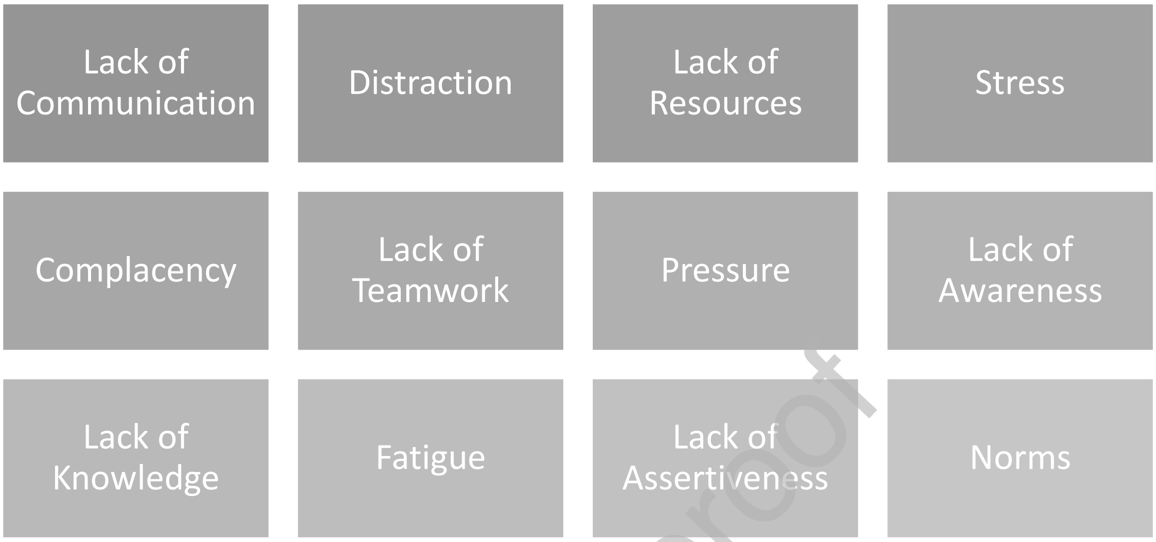

Figure 1: Human Factors Dirty Dozen (Dupont, 1997)

The **Human Factors Analysis and Classification Scheme (HFACS)** provides a more systematic approach to identifying precursors for human error leading to aviation accidents or incidents.

The HFACS framework was developed by Shappell and Wiegmann (2000) and is based on the groundwork of James Reason on safety and risk management (Shappell and Wiegmann, 2001). HFACS provides four levels of analysis: Organisation, Supervision, Preconditions for Unsafe Acts, and Unsafe Acts (Figure 2). Thus, it does not only focus only on human error alone, but also on the underlying preconditions that exist in the environment the human is working in.

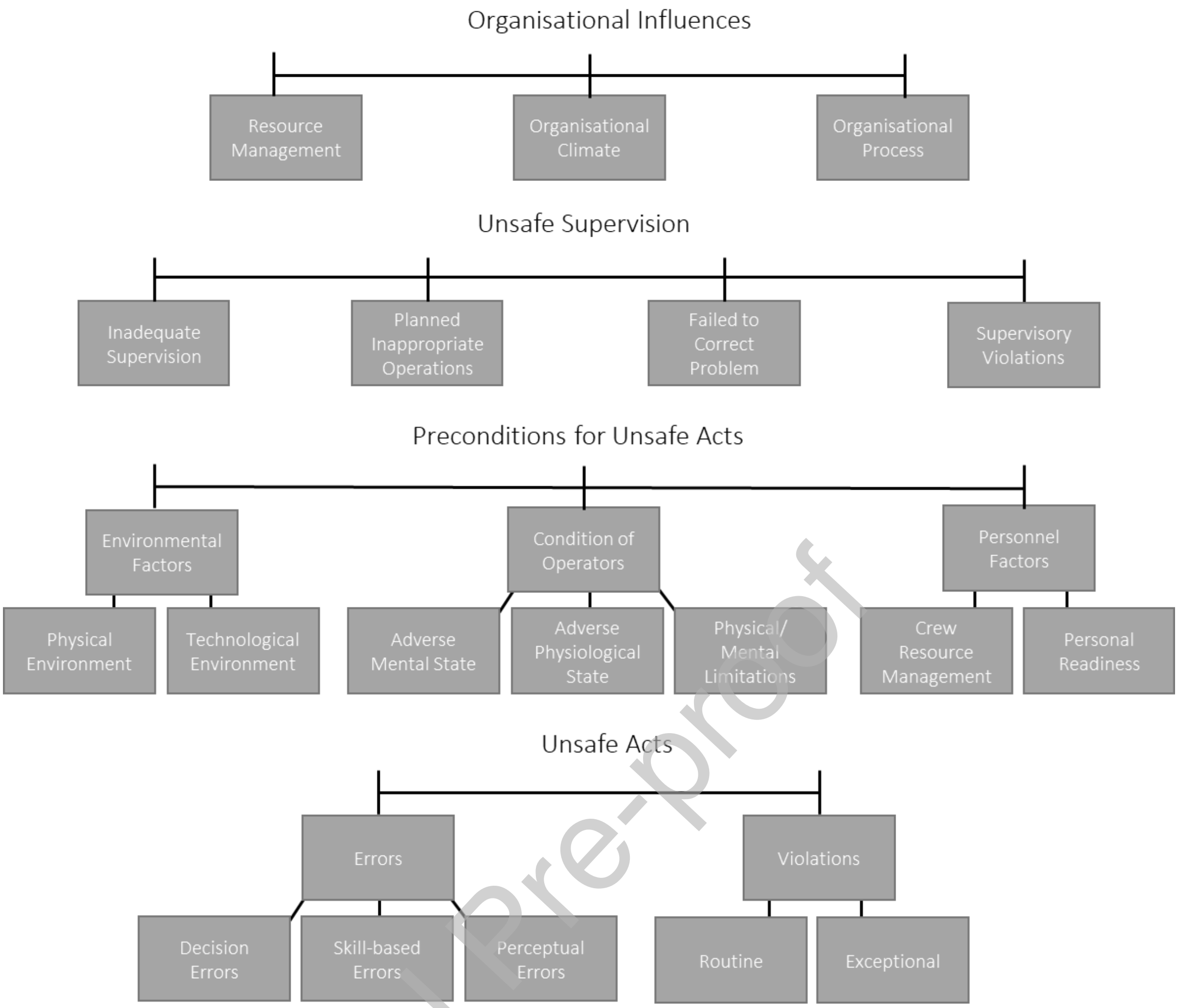

Figure 2: The Human Factors Analysis and Classification Scheme – HFACS (Shappell et. al., 2007)

HFACS has been used by aviation researchers and accident investigators, but also in the maritime, rail and the chemical sectors to identify potential active and latent system failures (Chauvin et. al., 2013; Wang et. al., 2020).

2. METHODOLOGY

A three-stage systematic content analysis of aviation accident and incident reports was undertaken, using the HF DD (Stage 1), HFACS (Stage 2) as guiding frameworks. This was akin to a template analysis (Stage 3) which is a special form of thematic analysis that emphasises the use of hierarchical coding but achieves a balance between a relatively high level of structure in the analysis of textual data with the potential of also allowing the identification of emerging themes that were not included in the original template (Brooks et al. 2015).

All three stages were based on the analysis of official accident and incident reports retrieved from official governmental national aviation accident investigation (please see Table 6 in the Appendix). The reports in those databases were evaluated against the following criteria: The search was limited to accidents and incidents between the years 2000 and 2020, thus limiting the reports to accidents and incidents that happened in the latest evolutionary stage in aviation safety, the system stage. Only commercial air transport accidents were examined, including turboprop and jet aircraft involved. Reports that have been included contained identifiable ground operations' causal or contributing factors. The initial search resulted in 105 accident and incident reports, while after the detailed screening 87 reports remained. Excluded reports could not provide sufficient information to be included in the analysis, for example caused by a superficial description of the occurrences. A list of the selected reports can be found in the Appendix – Table 6.

The strategy used in the current study employed three steps: First, it systematically analysed the selected reports and identified what happened, where, how, and what contributed to it. Main ground operational areas in which those accidents or incident occurred were defined and a template was developed for the classification and quantification of data and information. Second, it identified the main human error preconditions for accidents and incidents using the human factors 'dirty dozen' model and a more systemic analysis with the Human Factors Analysis and Classification Scheme (HFACS). Third, a thematic analysis is offered to unveil main areas in which either organisational, operational, procedural, or training improvements might be necessary. The data and information were coded into themes and categories relevant to identify the contribution areas of ground operations. This analysis aids to organise, structure, and quantify data and information with identifiable ground operations/ground services components. (Brooks et al., 2015) In addition, reliability measures for the applied methods and conducted analysis were applied. Intercoder reliability tests were applied to reduce subjectivity bias. (Feng, 2014; O'Connor & Joffe, 2020) The researchers read, sorted, and re-read the incidents until they reached agreement on the coding strategy (themes – codes). The tests for homogeneity of the codes did not show significant differences between the coders at the 0.05 level. To further ensure reliability with a test-retest check the researchers undertook the same task for a second time, three weeks later, resulting in an 84.2% agreement which is higher than the 80% prescribed level of acceptance (Miles and Huberman, 1994)

3. RESULTS & DISCUSSION

Analysis of Accidents and Incidents in Ground Operational Working Areas

The first level of analysis sought the operational areas of actions in which Ground Operations' failures or mismanagement contributed to accidents and incidents reported in the sample (Table 1). Those actions include aircraft weight and balance issues such as misplaced containers or loose load or error during weight planning; aircraft pushback and towing operations; ramp operations such as driving of ground support equipment or service cars on the apron; aircraft de-icing; aircraft arrival and departure, i.e., the preparation processes for aircraft arrival and departure (e.g., placing pylons or wheel chocks[1], check of the parking position); and aircraft marshalling and positioning procedures.

Table 1: Operational area related to the probable cause or major contributing factor

Working area of the probable cause & contributing factors	# of reports	%	Main findings	Accident Report Number (Appendix)
Aircraft weight and balance -Load -Unload -Load and unload	17 15 1 1	20	- Special cargo procedures - Misplaced Unit Load Device (ULD) - Communication	AR#: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 35, 51, 53, 54, 83
Aircraft Pushback / Towing	28	32	-Communication before and during pushback -Lack of experience	AR#: 13, 15, 16, 17, 19, 22, 26, 28, 32, 36, 39, 41, 43, 45, 48, 52, 55, 57, 58, 60, 64, 65, 67, 70, 72, 73, 80, 82
Ramp Driving	11	13	-Lack of awareness	AR#: 14, 18, 23, 25, 31, 34, 42, 66, 74, 75, 85

[1] When the aircraft arrives, pylons are placed to mark the aircraft perimeter, while the wheel chocks are placed to prevent the aircraft from moving.

De-icing	3	3	-Lack of or insufficient communication	AR#: 24, 29, 33
Aircraft arrival/departure -set-up/arrival -wrap-up/departure	21 11 10	24	-Lack of awareness	AR#: 20, 37, 38, 40, 44, 46, 49, 50, 56, 61, 62, 63, 68, 69, 76, 77, 78, 79, 81, 84, 86
Aircraft marshalling/positioning at the gate	4	5	-Lack of awareness -Lack of experience/training -Miscommunication	AR#: 27, 59, 71, 87
Other	3	3	-Lack of awareness	AR#: 21, 30, 47
TOTAL	87	100		

The majority of the accidents and incidents occur during Aircraft Pushback/Towing (32%), during aircraft arrival and departure operations (24%), and in relation to the weight and balance of the aircraft (20%) (see Table 1).

Thereafter we analysed the impact severity these GO failures. This impact was evaluated in terms of damage to the aircraft or equipment, and harm to persons such as the ground personnel, flight crew, or passengers (Table 2).

Severe damage to an aircraft or equipment ranges from damages requiring major repairs (AR# 32) to a total hull loss of the aircraft (AR# 1). In more than 30% of the reports (n=28), serious damage- to the aircraft or other ramp equipment was identified.

Table 2: Damage and injuries of selected reports[2]

	Damage to aircraft and equipment				Injury			
Severity	Negligible	Minor	Major	Hazardous/catastrophic	Negligible	Minor	Major	Hazardous/catastrophic

[2] The classification of incidents is based on the ICAO Risk Severity Table (ICAO, 2018, p.37), but has been simplified so that four categories are used instead of five. In the ICAO Risk Severity Table, the reports are classified in 'Hazardous' and 'Catastrophic' separately.

Severity definition	No damage to aircraft or equipment	Minor damage to aircraft or equipment, smaller operation limitations	Significant damage and operation disruptions	Serious damage or total hull loss of aircraft or equipment	No injuries	Small injury without consequences	Injury to people without long-term consequences	Serious injuries or death to people (e.g. personnel, crew, passengers)
Number of accidents and incidents	21	20	18	28	70	9	2	6
TOTAL in % (rounded numbers)	24%	23%	21%	32%	80%	10%	2%	7%

Human Factors Analysis

In exploring the Human Factors contribution to the reported accidents and incidents, the reports were first screened through the lens of HF DD as an accident or an incident can be attributed to several human error preconditions from the 'dirty dozen' framework. Then, the HFACS framework was used to further analyse the contributing factors. (Shappell & Wiegmann 2000)

Table 3: The Human Factors Dirty Dozen - relevance to the identified accidents and incidents

Human Factors Dirty Dozen	# of accidents & incidents reported	%
1. Lack of communication	**36**	**41.38**
2. Distraction	10	11.49
3. Lack of resources	**30**	**34.48**
4. Stress	13	14.94
5. Complacency	11	12.64
6. Lack of teamwork	0	0.00
7. Pressure	9	10.34
8. Lack of awareness	**54**	**62.07**

9. Lack of knowledge	8	9.19
10. Fatigue	4	4.59
11. Lack of assertiveness	2	2.29
12. Norms	15	17.24

In the HF DD analysis (Table 3), the three most prominent human error preconditions that can be considered as accident/incident causal or contributing factors are lack of awareness, lack of communication, and lack of resources.

Lack of awareness appeared in all operational areas of GO. During the turnaround, personnel may not be aware of errors on load sheets (AR# 9 & 10), or during the pushback operation, the pushback driver and wingwalker[3] may not be aware of the improper clearance to obstacles or another aircraft (AR# 28 & 32). This lack of awareness is often compounded by other human error preconditions, such as lack of communication or miscommunication (AR# 15, 40), lack of resources (AR# 42) or time pressure (AR# 6, 7). Miscommunication resulting in lack of awareness can involve unclear information on the payload for the aircraft (AR# 11, 12, 35), on the clearance of the aircraft to obstacles (AR# 15), and miscommunication between the GO and other subsystems (AR# 24, 29)

Lack of resources typically involves insufficient GO personnel numbers (e.g., loading team, missing a load planner or wingwalker - AR# 3, 6, 19), missing the necessary equipment (e.g. a radio, a de-icing vehicle or a missing belt loader -AR# 24, 84), or even not having the appropriate manuals (AR# 38, 46, 67, 83).

In the HFACS analysis that followed, the framework was to look at causes of these accidents and incidents from a more organisational perspective.

Table 4: Results of the Human Factors Analysis and Classification Scheme

HFACS	Causal Categories	# of reports	%

[3] Wingwalker: „A member of the ground crew whose primary job function is to walk alongside the aircraft's wing tip during aircraft ground movement (e.g. pushback, towing) to ensure the aircraft does not collide with any objects" (IATA, 2021-2, p.255)

Organisational Influences	Resource Management	23	26.44
	Organisational Climate	9	10.34
	Organisational Process	62	71.26
Unsafe Supervision	Inadequate supervision	7	8.05
	Planned inappropriate operations	7	8.05
	Failed to correct problem	9	10.34
	Supervisory violations	0	0
Preconditions for Unsafe Acts	Environmental Factors - Physical Environment - Technological Environment	17 19	19.54 21.84
	Condition of Operators - Adverse Mental State - Adverse Physiological State - Physical/Mental Limitations	33 0 13	37.93 0 14.94
	Personnel Factors - Crew Resource Management - Personal Readiness	44 1	50.57 1.15
Unsafe Acts	Errors - Decision Errors - Skill-based Errors - Perceptual Errors	33 20 46	37.93 22.98 52.87
	Violations - Routine - Exceptional	3 5	3.45 5.75

Table 4 shows that the main organisational factors causing or contributing to the accidents and incidents were ‘Organisational Processes’, ‘Perceptual Error’ and ‘Crew Resource Management’. In addition, ‘Decision Errors’ and ‘Adverse Mental State’ could also be observed as contributing human error factor in approx. one third of the accident reports respectively.

The main causal factor was related with ‘Organisational Processes’ (n=62, in 71.26% of the analysed accidents), in other words decisions and rules made within the organisation to govern the daily activities, such as operational processes, procedures, control, and oversight (Wiegmann and Shappell, 2000, 2001). This factor is mainly linked with a lack of necessary operational and safety processes (AR# 1, 36, 40) or with major failures in their implementation (AR# 2, 3, 7 19). Compounding factors include the lack of proper communication procedures (AR# 40), lack of reporting procedures (AR# 44), and insufficient training provision (AR# 44, 63). Other prominent factors were ‘Perceptual Error’ (n=46, in 52.87% of the analysed accidents), and ‘Crew Resource Management’ related activities or omissions (n=44, in 50.57% of the analysed accidents). The ‘Perceptual Error’ factor refers to an error caused by decreased sensory perception or a decision based on false information (Shappell & Wiegmann, 2000, 2001). Perceptual errors would be directly associated with ‘Lack of awareness’ in the HF DD analysis (AR# 78, 79, 83, 86). ‘Crew Resource Management’ (AR# 1, 5, 17) normally refers to communication, coordination, planning, and teamwork or the lack of these elements (Kanki et. al., 2019). An inadequate decision taken in and for a specific situation, not leading to the intended outcome are so called ‘Decision Errors’ (AR# 2, 12, 67): Adverse mental state includes mental conditions, such as stress, fatigue or even the personal motivation to complete a task, that limit the performance of the human factor (AR# 4, 19, 32). (Shappell & Wiegmann, 2000, 2001)

Emerging factors

During the analysis of accident and incident causes, several of the identified factors could not adequately be classified under the HF DD or HFACS frameworks. The most prevalent of these were Training and Education (only partly covered in HF DD and HFACS) (AR # 1, 19, 53), Oversight (AR# 12, 40, 46) and Rulemaking/Policymaking (AR# 33, 53, 87)

Integrating the factors identified in this study as the ones causing aviation accidents and incidents, Table 5 provides an overview of reasons for which human factor theme in GO have caused an accident or an incident over the last two decades.

Table 5: Thematic Analysis with HF Dirty Dozen Codes Included

Themes and sub-themes		# of reports	% of accidents or incidents
Training and Education	- Insufficient training - Insufficient personnel qualification - Lack of knowledge - Lack of experience	11 4 10 4	12.64 4.60 11.49 4.60
Communication	- Lack of communication - Wrong/insufficient communication	18 16	20.69 18.39
Culture	- Lack of organisational culture - Lack of safety culture	11 9	12.64 10.34
Rulemaking/Policymaking	- Lack of regulatory framework - Lack of guidance material	5 16	5.75 18.39
Procedures	- Lack of (proper) procedures - Insufficient procedures - Failure to follow procedures (2)	21 22 57	24.14 25.29 65.52
Oversight	- Inadequate regulatory oversight - Insufficient internal oversight (e.g. audits, control, observation) - Wrong norms established & not detected	7 12 6	8.05 13.79 6.90
Resources	- Lack of resources - Incorrect planning of resources*	16 7	18.39 8.05
Management	- Insufficient change management - Insufficient supervision	4 17	4.60 19.54
Environmental Influences	- Technical problems/deficiencies - Physical environment (e.g. severe weather)	14 12	16.09 13.79
Front-line - Human Factors	- Distraction - Stress - Complacency - Lack of teamwork - Pressure - Lack of situational awareness (1) - Fatigue	8 9 8 0 6 58 3	9.19 10.34 9.19 0.00 6.90 66.67 3.45

	- Lack of assertiveness - Incorrect interpretation of information	0 15	0.00 17.24

One accident or incident often has various influencing factors across the themes and categories. For example, the failure to follow prescribed procedures can be related to wrong norms, an insufficient safety culture, the lack of resources, high time pressure, and even personal stress (AR#17, 29). Two sub-themes can be highlighted: (1) lack of awareness and (2) failure to follow prescribed procedures, which both can be found in nearly two-thirds of the analysed reports (Table 5).

Although the analyses do not provide a complete picture, due to the varying degree of detail in the accident reports, they show unique human error preconditions for the subsystem ground operations in all three stages of the analysis. While there are many similarities to other subsystems in the influencing factors of accidents and incidents (human error categories, such as situational awareness), there are also major differences, such as the failure to follow prescribed procedures. For an adapted human error management approach, one must consider these differences and similarities, as well as available human error management approaches in other subsystems and other industries.

Even though the categories of human error preconditions show similarities across subsystems, how these preconditions for accidents and incidents are managed and mitigated must be adapted to the distinct characteristics of the subsystem. To date, ground operations safety research and academic literature are very limited in addressing these and other safety issues (Muecklich et. al., 2019, Ek & Akselsson, 2004, McDonald & Fuller, 1997). While industry-related guidance exists, such as IATA IGOM (IATA, 2021-2) or ICAO Manuel on Ground Handling (ICAO, 2019), these are potentially not or limited research-based and are not focused on the safety issues that emerged from this study.

The idea of a Ramp Resource Management (RRM) concept already exists, and similarly to Crew Resource Management (CRM), focuses on the non-technical and human factors issues in the subsystem. Nevertheless, the RRM is neither embedded in any ground operations regulatory framework nor otherwise widely present within the ground operations industry – while the latest information is dated to 2013 and earlier (Muecklich et. al., 2019; EASA, 2013). Thus, research-based existing knowledge and application of safety methods are limited, while it must be noted that more industry guidance is available. The main results of this study, with human error preconditions in different areas, are similar to those identified and discussed in other subsystems, such as flight operations (Helmreich & Foushee, 2019; Ford et. al., 2014; Flin et al., 2002) or air traffic control (Eurocontrol, 2021; Woldring, 1999; Andersen & Bove, 2000). In those primary subsystems, these issues are included in their safety management concepts, specifically in CRM and Team Resource Management (TRM) training frameworks. As an example, communication and lack of awareness are integral parts of the CRM concept (Kanki et. al., 2019). Both concepts adapt the training on the identified safety issues on the distinct characteristics of the specific subsystem (Flin et. al., 2002; Eurocontrol, 2021).

We identified human error preconditions for accidents in the subsystem ground operations, as the first step for a better comprehension of ground operations characteristics and influences. This subsystem-specific analysis is considered critical as ground operations have a unique working environment and task design, as well as different characteristics of the people working in this subsystem compared to the other subsystems in aviation (Balk et. al., 2012). In addressing the human error preconditions, these characteristics must be understood and considered in designing adapted human error management approaches, such as a RRM concept.

The human error analysis models focus on analysing a specific accident or incident report, or specific subsystems, but none yet in a wider system context displaying interdependencies between subsystems, this is also limited by the current reporting frameworks - how accidents and incidents in ground operations are reported. There exists no standard except for ICAO Annex 13 on severe accidents (ICAO, 2020).

The results suggest that current human error analysis models may need to be extended to a more systemic approach – aligning the developments of the evolution of safety on the system level (Leveson, 2020; ICAO, 2018; Leveson et. al. 2009). HFACS is already on the organisational level, but aviation is more complex and interactions and dependencies between subsystems must also be considered. Thus, as a result of all analyses, it is recommended to consider the broader organisation and aviation system also from a quantitative perspective to identify additional causal and contributing factors and ultimately address the problem (i.e. overrepresentation of particular human error factors per working area and severity level, or correlation and interdependencies of human error factors).

For a more complete picture of the current ground operations framework and the role of human factors in ground operations, current rules, regulations, standards, and guidance material shall be reviewed for detecting potential gaps. Both, this accident analysis and the analysis of regulations and standards could provide the basis for a comprehensive human error management framework.

Finally, a potential outcome could be a comprehensive RRM framework to address the safety issues as identified in this study, but in an adapted and thus effective concept for ground operations and the people, equipment, and information in the specific subsystem, while not disregarding the wider systematic context.

Limitations

Although every effort was made to identify the reports most relevant to this study, the research team was faced with a few challenges to that end. First, the accident and incident reporting standards differ from country to country and are only guided by a few international/supranational frameworks or laws, such as ICAO Annex 13 ‘Aircraft Accident and Incident Investigation’ or ‘Regulation (EU) No 376/2014 ‘on the reporting, analysis and follow-up of occurrences in civil aviation’ (ICAO, 2020; European Parliament and Council of the European Union, 2014). Australia, for example, publishes occurrences with smaller payload discrepancies (e.g. AR# 8, AR#11 and AR# 12), and other countries do not publish these occurrences, but only more severe incidents and accidents. Not all reports that have been identified and used in this study provide a thick description of the accidents (e.g. AR# 1, x 42), with some providing only a short synopsis over the situation (e.g. AR# 13, 16). As a result, some accident and incident causes may have not been detected in the analysis and the findings cannot be considered as fully comprehensive.

4. CONCLUSION

All stages of this study showed that human factors in Ground Operations can and do influence the safety of the aircraft and the people acting around it. Consequences can reach from no or only minor damages or injuries (Example: AR# 3, 19, 21) to serious or even fatal damages or injuries (Examples: AR# 44, 45, 90) (Table 2). The results revealed that the main causal and contribution human error factors in ground operations related accidents and incidents based on the three stage analysis process are: 1) lack of awareness, 2) lack of communication, and 3) lack of resources (HF DD – Table 3), 1) organisational processes, 2) perceptual error and 3) crew resource management (HFACS – Table 4), and 1) lack of awareness and (2) failure to follow prescribed procedures (Thematic Analysis – Table 5). As a result, a reduction of ground operations-related accidents and incidents cannot only reduce harm to people or damage to equipment, but also increases efficiency, effectiveness, and the financial health and sustainability of an organisation and the system (IATA, 2022-2). The identified human error preconditions for accidents and incidents are recommended to be addressed in an adapted ground operations-related context. Additionally, the interdependencies and correlations between human error preconditions in aviation accidents shall be explored. Based on the results of this study, it is recommended to evaluate if the development of a comprehensive RRM framework, including training, education, communication, etc., as detected in the themes, can be beneficial for the individual organisation and the aviation system safety. An adapted RRM concept would provide a standard framework for ground operations that focuses on non-technical skills and tasks, similar to the CRM concept for flight operations, but adapted to the needs and characteristics of ground operations. The ten emerging themes (Table 5) may serve as a first framework for enhancing specific topics in an RRM concept and to guide further research on human error in the critical GO working areas, namely aircraft pushback/towing, aircraft arrival/departure, and aircraft weight and balance. All themes shall be viewed in the system context and considering interactions with other operational sub-systems (flight operations, maintenance operations, air traffic control). In addition, it must be examined which methods and tools are already applied in the industry, by either industry associations or ground handling service providers themselves. The research on ground operations is limited, but not necessarily the industry guidance, therefore safety measures applied within ground handling service providers should be assessed, including ICAO and IATA guidance material (IATA, 2021-2; ICAO, 2019).

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6. Appendix

Table 6: Overview of selected reports

Accident Report #	Name of Report	Year of Accident, Incident, or Occurrence	Reference/Link
AR#1	Steep Climb and Uncontrolled Descent During Takeoff National Air Cargo, Inc., dba National Airlines	2013	https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR1501.pdf
AR#2	Aircraft loading-related occurrence involving Airbus A330-303, VH-QPD, Sydney Airport, New South Wales, on 17 December 2017	2017	http://www.atsb.gov.au/publications/investigation_reports/2018/aair/ao-2018-003/
AR#3	Aircraft loading event involving Fokker F28, VH-NHV, Perth Airport, Western Australia, on 3 February 2017	2017	http://www.atsb.gov.au/publications/investigation_reports/2017/aair/ao-2017-019/
AR#4	Aircraft loading involving Boeing 737, ZK-TLK, Sydney Airport, NSW, on 17 December 2016	2016	http://www.atsb.gov.au/media/5772697/ao-2017-002_final.pdf
AR#5	Loading related event involving Airbus A320, VH-VGI, Melbourne Airport, Victoria, on 21 December 2016	2016	http://www.atsb.gov.au/publications/investigation_reports/2016/aair/ao-2016-177/
AR#6	Loading related event involving Airbus A320, VH-VQC, Gold Coast Airport, Queensland, on 29 October 2016	2016	http://www.atsb.gov.au/publications/investigation_reports/2016/aair/ao-2016-145/
AR#7	Loading event involving Airbus A320, VH-VFN, Sydney Airport, NSW, on 8 September 2016	2016	http://www.atsb.gov.au/publications/investigation_reports/2016/aair/ao-2016-119/
AR#8	Loading event involving an Airbus A330, VH-QPJ, at Bangkok, Thailand on 23 July 2015	2015	http://www.atsb.gov.au/publications/investigation_reports/2015/aair/ao-2015-088/
AR#9	Loading event involving a Bombardier DHC-8, VH-LQK, at Brisbane Airport, Qld on 25 August 2014	2014	http://www.atsb.gov.au/publications/investigation_reports/2014/aair/ao-2014-145/

AR#10	Loading related events involving a Boeing 737, VH-YIR, Bali, Indonesia on 26 May and an Airbus A330, VH-XFE, at Perth, WA on 16 June 2014	2014	http://www.atsb.gov.au/publications/investigation_reports/2014/aair/ao-2014-110/
AR#11	Aircraft loading event - Airbus A330-202, VH-EBB, Sydney Airport NSW, 4 July 2009	2009	http://www.atsb.gov.au/publications/investigation_reports/2009/aair/ao-2009-034/
AR#12	Weight and balance event - Airbus A330-303, VH-QPJ, Sydney Aerodrome, New South Wales, 6 March 2009	2009	http://www.atsb.gov.au/publications/investigation_reports/2009/aair/ao-2009-011/
AR#13	Collision involving a Boeing B737, VH-VZZ and a catering vehicle at Sydney Airport, NSW, on 14 October 2017	2017	http://www.atsb.gov.au/media/5775312/ao-2017-099_final.pdf
AR#14	Occurrence #1: ON GROUND/WATER COLLISION; Phase of Operation: TAXI - FROM LANDING	2007	https://app.ntsb.gov/pdfgenerator/ReportGeneratorFile.ashx?EventID=20071231X02012&AKey=1&RType=Summary&IType=LA
AR#15	N725PS: Bombardier, Inc. / CL-600-2C10, N228PS: Bombardier, Inc. / CL-600-2B19	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: NYC08LA234
AR#16	N122UX: Beech / 1900D	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: DEN08LA151
AR#17	N254WN: Boeing / 737-700	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: WPR09IA033
AR#18	N8698A: BOMBARDIER INC / CL-600-2B19	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: DCA09FA011
AR#19	Date & Time: December 26, 2012, 02:15 Local Registration: N612FE Aircraft: McDonnell Douglas MD-11F	2012	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: DCA13CA035
AR#20	Date & Time: February 2, 2012, 17:05 Local Registration: N912SW Aircraft: Bombardier CL600	2012	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: DCA12CA035

	2B19		
AR#21	Date & Time: December 23, 2008, 01:02 Local Registration: N486EV Aircraft: Boeing 747-212B	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: CEN09LA114
AR#22	Date & Time: June 10, 2011, 17:58 Local Registration: N571UA Aircraft: Boeing 757-222	2011	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: DCA11CA073
AR#23	Date & Time: October 3, 2012, 20:10 Local Registration: N894AT Aircraft: Boeing 717-200	2012	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: CEN13LA004
AR#24	Date & Time: January 16, 2012, 07:00 Local Registration: N839EX Aircraft: Boeing DHC-8-102	2012	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: ERA12LA147
AR#25	Date & Time: December 22, 2011, 14:37 Local Registration: N469WN Aircraft: Boeing 737-7H4	2011	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: CEN12IA123
AR#26	Date & Time: May 31, 2011, 12:15 Local Registration: N526UA Aircraft: Boeing 757-222	2011	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: WPR11LA300
AR#27	Date & Time: February 16, 2010, 06:35 Local Registration: N226SW Aircraft: Embraer EMB-120ER	2010	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: WPR10IA135
AR#28	Date & Time: December 28, 2008, 07:00 Local Registration: N585NW Aircraft: Boeing 757-351	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: WPR09FA068
AR#29	Date & Time: December 24, 2008, 07:00 Local Registration: N516AS Aircraft: Boeing 737-890	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: WPR09IA065
AR#30	Date & Time: December 20, 2008, 07:47 Local Registration: N771AS Aircraft: Boeing 737-4Q8	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: ANC09IA015
AR#31	Date & Time: December 18,	2009	https://data.ntsb.gov/carol-main-

	2009, 11:15 Local Registration: N515AE Aircraft: Bombardier CL600 2C10		public/basic-search NTSB No: DCA10CA018
AR#32	Date & Time: January 12, 2008, 19:29 Local Registration: N705SK Aircraft: Bombardier, Inc. CL-600-2C10	2008	https://data.ntsb.gov/carol-main-public/basic-search NTSB No: SEA08LA061
AR#33	Type of Occurrence: Accident Date: 20 January 2015 Location: Nuremberg Airport Aircraft: Transport aircraft Manufacturer / Model: Fokker Aircraft B.V. / F28 Mark 0100 Injuries to Persons: None Damage: Aircraft severely damaged Other Damage: None	2015	https://www.bfu-web.de/EN/Publications/Investigation%20Report/2015/Report_15-0059-AX_Fokker100_Nurnberg.pdf?__blob=publicationFile
AR#34	Type of Occurrence: Accident Date: 14 December 2011 Location: Berlin-Tegel Airport Aircraft: Airplane Manufacturer / Model: Bombardier / DHC8-300 Injuries to Persons: One person severely injured	2011	https://www.bfu-web.de/EN/Publications/Investigation%20Report/2011/Report_11_AX001_DHC8_Berlin-Tegel.pdf?__blob=publicationFile
AR#35	Kind of occurrence: Serious incident Date: 29 November 2002 Location: Dortmund Airport Aircraft: transport category airplane Manufacturer/type: Boeing Company / Boeing 737-800 Injuries to persons: no injuries Damage to aircraft: airplane slightly damaged	2002	https://www.bfu-web.de/EN/Publications/Investigation%20Report/2002/Report_02_EX007-0_Dortmund_B737.pdf?__blob=publicationFile
AR#36	Date and hour: 24 November 2013 at 09:46 UTC Aircraft type: Boeing 757-200 Year of manufacture: 2000 Total flight time: 43125:13 FH Type of engine: 2 Rolls-Royce RB211-535E4, high-bypass turbofan engines Operator: US Airways1 Accident location: EBBR -	2013	https://mobilit.belgium.be/sites/default/files/downloads/2013-25%20Final%20report.pdf?language=fr

	Brussels Airport, Belgium Type of flight: Commercial Air Transport - Passengers Phase: Pushback/towing		
AR#37	Cargo door opening on take-off Bradley Air Services Ltd. (First Air) Boeing 727-225 C-FIFA Corcaigh International Airport, Ireland 20 July 2001	2001	https://www.tsb.gc.ca/eng/rapports-reports/aviation/2001/a01f0094/a01f0094.html#3.0
AR#38	Cargo Door Opening on Take-Off Kelowna Flightcraft Air Charter Ltd. Boeing 727-227 C-GJKF Regina, Saskatchewan 13 December 2006	2006	https://www.tsb.gc.ca/eng/rapports-reports/aviation/2006/a06c0204/a06c0204.html#3.0
AR#39	Ground collision, fire, and evacuation WestJet Airlines Ltd., Boeing 737-800, C-FDMB and Sunwing Airlines Inc., Boeing 737-800, C-FPRP Toronto/Lester B. Pearson International Airport, Ontario 05 January 2018	2018	https://www.tsb.gc.ca/eng/rapports-reports/aviation/2018/a18o0002/a18o0002.html
AR#40	Investigation of causes of an incident at Airport Karlovy Vary - fall of a person from the aircraft A320, registration VQ-BRE, on 6 August 2013	2013	https://uzpln.cz/pdf/incident_nke8P5BP.pdf
AR#41	Investigation of the ACCIDENT Allitalia airlines, MD 80 At LKPR on 26th May 2005	2005	https://uzpln.cz/pdf/incident_MzAxFWNK.pdf
AR#42	Accident 16-12-2016 involving BOMBARDIER CL600 2D24 900 OY-KFF	2016	https://en.havarikommissionen.dk/media/9449/l_2016_havari_510-2016-321_oykff_motorfly_koebenhavn-ekch.pdf
AR#43	Accident 26-12-2016 involving	2016	https://en.havarikommissionen.dk/media/10573/l_2016_havari_510-2016-322_sedst-

	BAE AVRO RJ100 SE-DST and AIRBUS A340 OY-KBC		oykbc_motorfly_koebenhavn-ekch.pdf
AR#44	C6/2008L A serious incident on the apron of Helsinki-Vantaa airport on 23 September 2008	2008	https://turvallisuustutkinta.fi/en/index/tutkintaselostukset/ilmailuonnettomuuksientutkinta/tutkintaselostuksetvuosittain/ilmailu2008/c62008lvaaratilannehelsinki-vantaanasema.html
AR#45	Accident to the Boeing B777-333 ER registered C-FNNQ on 24 July 2019 at Paris-Charles de Gaulle (Val-d'Oise)	2019	https://www.bea.aero/fileadmin/user_upload/BEA2019-0413.en.pdf
AR#46	C10/2003L Taxiing incident at Helsinki-Vantaa Airport on 6 December 2003	2003	https://turvallisuustutkinta.fi/en/index/tutkintaselostukset/ilmailuonnettomuuksientutkinta/tutkintaselostuksetvuosittain/ilmailu2003/c102003lrullausvauriohelsinki-vantaalla6.html
AR#47	C7/2005L Falling of passenger stairs at Rovaniemi airport on 14 December 2005	2005	https://turvallisuustutkinta.fi/en/index/tutkintaselostukset/ilmailuonnettomuuksientutkinta/tutkintaselostuksetvuosittain/ilmailu2005/c72005lmatkustajaportaidenkaatuminenrova.html
AR#48	Accident to the Embraer 190 registered F-HBLF occured on 19/04/2014 at Paris Charles-de-Gaulle Airport (95)	2014	https://www.bea.aero/en/investigation-reports/notified-events/detail/accident-to-the-embraer-190-registered-f-hblf-occured-on-19-04-2014-at-paris-charles-de-gaulle-airport-95/
AR#49	Accident to the Airbus A320 registered F-HBNK on 11 September 2016 at Bastia Poretta (2B)	2016	https://www.bea.aero/fileadmin/uploads/tx_elydbrapports/BEA2016-0582.en.pdf
AR#50	Aircraft Embraer 190 registered G-LCYJ Date and time 21 January 2012 à 08 h 20 UTC(1) Operator BA CityFlyer Place Chambéry Aix-les-bains Airport (73) Type of flight Scheduled public transport of passengers	2012	https://www.bea.aero/fileadmin/documents/docspa/2012/g-yj120121.en/pdf/g-yj120121.en_06.pdf

AR#51	Erroneous takeoff performance calculation, Boeing 777 . On21 April 2017	2017	https://www.onderzoeksraad.nl/en/page/4808/erroneous-takeoff-performance-calculation-boeing-777
AR#52	Collision with tug, Boeing 737-400, Amsterdam Airport Schiphol	2006	https://www.onderzoeksraad.nl/en/page/1104/collision-with-tug-boeing-737-400-amsterdam-airport-schiphol
AR#53	Tail strike during take-off, Boeing 737-800, Rotterdam Airport	2003	https://www.onderzoeksraad.nl/en/page/910/tail-strike-during-take-off-boeing-737-800-rotterdam-airport
AR#54	Final Report: Serious Incident ATR 72-212A, (EI-FAV) Dublin Airport Ireland, 23 July 2015 Report - 2018-002	2015	http://www.aaiu.ie/node/1153
AR#55	Final Report: Serious Incident Airbus A320, (EC-LVQ) Dublin Airport Ireland, 27 September 2017 Report - 2018-009	2017	http://www.aaiu.ie/sites/default/files/report-attachments/REPORT%202018-009.pdf
AR#56	Serious Incident: A330-300, EI-ORD, Dublin Airport, 28 December 2005, Report No: 2007-007	2005	http://www.aaiu.ie/sites/default/files/report-attachments/REPORT%202007_007.pdf
AR#57	Accident: Bombardier BD-700-1A10, N20EG and Bombardier BD-700-1A10, N6VB, Dublin Airport, 4 July 2007: Report No 2008-010	2007	http://www.aaiu.ie/sites/default/files/upload/general/10715-2008010_N20EG_AND_N6VB-0.PDF
AR#58	Incident: Airbus A321 G-MIDH, Dublin Airport, 15 Jan 2000: Report No 2000-006	2000	http://www.aaiu.ie/sites/default/files/report-attachments/3558-REPORT_2000_006-0.PDF
AR#59	Aircraft accident to YK-AHB at Stockholm/Arlanda airport, AB county.	2006	https://www.havkom.se/assets/reports/rl2007_23e.pdf
AR#60	AIRBUS A380-800, REGISTRATION 9V-SKA PUSHBACK INCIDENT IN SINGAPORE CHANGI AIRPORT 10 JANUARY 2008	2008	https://www.mot.gov.sg/docs/default-source/about-mot/investigation-report/10-jan-2008.pdf
AR#61	AIRBUS A320, REGISTRATION 9M-AHA FOREIGN OBJECT INGESTION INCIDENT	2010	https://www.mot.gov.sg/docs/default-source/about-mot/investigation-report/final-2010-feb-28.pdf

	AT SINGAPORE CHANGI AIRPORT ON 28 FEBRUARY 2010		
AR#62	CONTACT BETWEEN AIRBUS A320 AND AEROBRIDGE 5 OCTOBER 2012	2012	https://www.mot.gov.sg/docs/default-source/about-mot/investigation-report/contact-between-airbus-a320-and-aerobridge---final-report.pdf
AR#63	BOEING B777-200, REGISTRATION 9V-SRP CARGO CONTAINER INGESTION 19 DECEMBER 2013	2013	https://www.mot.gov.sg/docs/default-source/about-mot/investigation-report/container-ingestion-19-dec-13---fr.pdf
AR#64	B737-800, REGISTRATION 9V-MGM PUSHBACK INCIDENT 6 December 2015	2015	https://www.mot.gov.sg/docs/default-source/about-mot/investigation-report/b738-(9v-mgm)-pushback-incident-6-dec-2015-final-report.pdf
AR#65	GROUND INCIDENT INVOLING M/S ETHIOPIAN AIRLINES AIRCRAFT ET-AMG AND M/S AIR INDIA AIRCRFT VT-EXD AT DELHI ON 08.08.2017	2017	http://164.100.60.133/accident/reports/incident/VT-EXD.pdf
AR#66	Final investigation report on ground incident to m/s alliance air ATR42-320 aircraft vt-abo with jet airways passenger coach on 22.12.2015 at kolkata airport	2015	http://164.100.60.133/accident/reports/incident/VT-ABO.pdf
AR#67	General Civil Aviation Authority Air Accident Investigation Department Abu Dhabi, UAE 02/2010 FINAL REPORT On AIRCRAFT INCIDENT INVESTIGATION Ground Collision During Parking of the National Air Services Gulfstream GIV-X (G450), Registration N452NS Dubai International Airport, United Arab Emirates Feb. 28th, 2010	2010	https://www.gcaa.gov.ae/en/departments/airaccidentinvestigation/Pages/InvestigatorMagazinesView.aspx?min=mxkazpYdJ0&type=ir
AR#68	INCIDENT Aircraft Type and Registration:	2005	https://www.gov.uk/aaib-reports/airbus-a320-lz-bha-19-june-

	Airbus A320, LZ-BHA No & Type of Engines: 2 CFM56-5A turbofan engines Year of Manufacture: 1989 Date & Time (UTC): 19 June 2005 at 0755 hrs Location: Stand 27, Belfast International Airport, Northern Ireland		2005
AR#69	INCIDENT Aircraft Type and Registration: Boeing 767-200, EI-DBW No & Type of Engines: 2 General Electric CF6-80C2 turbofan engines Year of Manufacture: 1987 Date & Time (UTC): 12 April 2005 at 1015 hrs Location: London Gatwick Airport, West Sussex	2005	https://www.gov.uk/aaib-reports/boeing-767-200-ei-dbw-12-april-2005
AR#70	INCIDENT Aircraft Type and Registration: Fokker 100, D-AFKC No & Type of Engines: 2 Rolls Royce Tay 650-15 turbofan engines Year of Manufacture: 1996 Date & Time (UTC): 18 November 2010 at 1445 hrs Location: London Heathrow Airport	2010	https://www.gov.uk/aaib-reports/fokker-100-d-afkc-18-november-2010
AR#71	SERIOUS INCIDENT Aircraft Type and Registration: 1) Boeing 737, 9H-BBJ 2) Embraer 145LR, G-CISK Date & Time (UTC): 10 January 2018 at 1238 hrs Location: Bristol Airport	2018	https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-737-9h-bbj-and-embraer-145lr-g-cisk
AR#72	ACCIDENT Aircraft Type and Registration: 1) Boeing 737-8AS, EI-ENL 2) Boeing 737-8AS, EI-DLJ Date & Time (UTC): 28 June 2014 at 0546 hrs Location: London Stansted Airport	2014	https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-737-8as-ei-enl-and-boeing-737-8as-ei-dlj
AR#73	ACCIDENT Aircraft Type and Registration:	2017	https://www.gov.uk/aaib-reports/aaib-investigation-to-airbus-a320-214-g-

	Airbus A320-214, G-EZTV Date & Time (UTC): 3 March 2017 at 1825 hrs Location: Stand 1, Manchester Airport		eztv
AR#74	ACCIDENT Aircraft Type and Registration: Boeing 737-8JP(WL), LN-DYS Date & Time (UTC): 23 December 2014 at 0602 hrs Location: London Gatwick Airport	2014	https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-737-8jp-wl-ln-dys
AR#75	ACCIDENT Aircraft Type and Registration: Boeing 737-8AS, EI-EXF Date & Time (UTC): 3 December 2014 at 0815 hrs Location: London Stansted Airport	2014	https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-737-8as-ei-exf
AR#76	ACCIDENT Aircraft Type and Registration: Boeing 737-45D, SP-LLB Date & Time (UTC): 20 February 2006 at 1140 hrs Location: Stand 114, London Heathrow Airport	2006	https://www.gov.uk/aaib-reports/boeing-737-45d-sp-llb-20-february-2006
AR#77	INCIDENT Aircraft Type and Registration: Britten-Norman BN2A Mk III-1 Trislander, G-LCOC Date & Time (UTC): 7 June 2006 at 0530 hrs Location: Saint Brieuc, Brittany, France	2006	https://www.gov.uk/aaib-reports/britten-norman-bn2a-mk-iii-1-trislander-g-lcoc-7-june-2006
AR#78	ACCIDENT Aircraft Type and Registration: 1) DHC-8-402, G-JECK 2) EMB-145EP, G-SAJS Date & Time (UTC): 16 June 2020 at 1646 hrs Location: Aberdeen International Airport	2020	https://www.gov.uk/aaib-reports/aaib-investigation-to-dhc-8-402-g-jeck-and-emb-145ep-g-sajs
AR#79	SERIOUS INCIDENT Aircraft Type and Registration: Boeing 747-436, G-CIVU Date & Time (UTC): 20 December 2019 at 1543 hrs	2019	https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-747-436-g-civu

	Location: London Heathrow Airport		
AR#80	ACCIDENT Aircraft Type and Registration: Boeing 737-800, EI-DYM Date & Time (UTC): 12 May 2011 at 0815 hrs Location: Liverpool John Lennon Airport	2011	https://www.gov.uk/aaib-reports/boeing-737-800-ei-dym-12-may-2011
AR#81	ACCIDENT Aircraft Type and Registration: Boeing B737-800, EI-DAI Date & Time (UTC): 21 July 2005 at 1655 hrs Location: London Stansted Airport, Essex	2005	https://www.gov.uk/aaib-reports/boeing-b737-800-ei-dai-21-july-2005
AR#82	ACCIDENT Aircraft Type and Registration: Airbus A320 -233, HA-LPJ Date & Time (UTC): 12 March 2009 at 0902 hrs Location: Stand 40, London Luton Airport	2009	https://www.gov.uk/aaib-reports/airbus-a320-233-ha-lpj-correction-12-march-2009
AR#83	INCIDENT Aircraft Type and Registration: Saab-Scania AB SF340B, G-LGNH No & Type of Engines: 2 General Electric CT7-9B turboprop engines Year of Manufacture: 1993 Date & Time (UTC): 2 January 2005 at 1405 hrs Location: Sumburgh Airport, Shetland Isles, Scotland	2005	https://www.gov.uk/aaib-reports/saab-scania-ab-sf340b-g-lgnh-2-january-2005
AR#84	ACCIDENT Aircraft Type and Registration: Boeing 737-8AS, EI-EBR Date & Time (UTC): 17 December 2014 at 0605 hrs Location: London Luton Airport	2014	https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-737-8as-ei-ebr
AR#85	ACCIDENT Aircraft Type and Registration: Airbus A380, VH-OQD Date & Time (UTC): 14 January 2012 at 1045 hrs Location: London Heathrow Airport	2012	https://www.gov.uk/aaib-reports/airbus-a380-vh-oqd-14-january-2012

AR#86	Aircraft Type and Registration: Boeing 747-4Q8, G-VTOP Date & Time (UTC): 16 November 2004 at 0915 hrs Location: Stand 327, London Heathrow Airport	2004	https://www.gov.uk/aaib-reports/boeing-747-4q8-g-vtop-16-november-2004
AR#87	Aircraft Accident Report No: 2018/01	2018	https://www.mot.gov.my/en/AAIB%20Statistic%20%20Accident%20Report%20Document/2018/07%20July%202018.pdf

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: