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Human Error Patterns in Commercial Aviation Accidents: An Analysis of HFACS Application Across Flight Phases Perspective in Bangladesh

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Abstract: The present study focuses on directing the lean research on accidents during flight instruction by evaluating accidents that happen during commercial aviation flights in Bangladesh. This research analyses investigative reports of 17 accidents involving commercial aviation flights in Bangladesh from 2015 to 2022, sourced from the “Aircraft Accident Investigation Committee of Bangladesh” (AAIC-BD). To systematically assess and categorize the contributing causes of these accidents, the “Human Factors Analysis and Classification System” (HFACS) was applied. This paper is the first attempt to employ the Human Factors Analysis and Classification System (HFACS) framework in investigating the causative factors in commercial aircraft crashes in Bangladesh. The review of 17 accidents showed that the most common cause was an error of skill, which was preceded by the error of choice and unfavorable psychological conditions. By establishing these key patterns of human errors, the proposed study will be used to design specific safety interventions and improve aviation safety in the expanding commercial sector in Bangladesh.

Keywords: *Commercial Aviation; Human Error; Pilot Training; HFACS; Accident Investigation*

Introduction: Bangladesh represents one of the most rapidly expanding aviation markets globally. This growth presents significant safety challenges due to increasing traffic density and operational complexities. Human error still accounts for nearly 80% of aviation accidents in global skies, despite high-tech systems and strict safety rules. “Human Error Patterns in Commercial Aviation Accidents: An Analysis of HFACS Application Across Flight Phases Perspective in Bangladesh” uses HFACS structure to classify and analyze errors within the separate phases of a flight—taxi, takeoff, cruise, approach/landing and landing rollout.

This study aims to investigate the characteristics and extent of human error in Bangladesh. In doing so, we adopt the HFACS perspective. This will provide useful insight into potential Bangladeshi solutions for some common pattern causes. The results of the study would provide considerable experience in safety interventions and application of the HFACS framework conducted for the new aviation sector. This will also create a sense of urgency to lower accidents and incidents in an environment of expanding air navigation practices.

The airline industry has been suffering from an ongoing continuation of incidents and accidents. This necessitates understanding and addressing the fundamental issues that contribute to such occurrences. Indeed, while much is known about technological and mechanical failure modes, the systematic analysis of human error patterns lags behind. This research aims to provide insights into the scientific fields that are not currently known in depth by applying the HFACS method. This will enable us to identify human error-induced aviation accidents according to different phases of flight. This approach is expected to reveal context-specific insights of significant operational relevance in Bangladesh and should facilitate focused safety improvement. There has not been enough study on the use of the HFACS framework in examining incidents and accidents in aviation within Bangladesh. This has resulted in the non-availability of literature for use to take preventive measures against potential accidents and incidents. This study will bear significance to aviation safety practitioners, policymakers and the airline industry to make better decisions through the articulation of effective and efficient strategies. The study promises to advance aviation safety standards and reduce considerably the gap that exists between reality and the desirable to ensure the safety and security of passenger’s, crew and material. This paper will critically examine the nature of human error in the Bangladeshi commercial aviation by applying the framework of the Human Factors Analysis and Classification System (HFACS). The particular objectives are to recognize and classify the existing human error patterns in commercial airline accidents, to establish the taxonomy of human error across critical flight phases (taxi, takeoff, cruise and approach/ landing), to carry out a comparative analysis of error type according to the severity of injuries (fatal and non-fatal accidents) and finally to come up with evidence-based recommendations that can lead to prevention of human error in airline operations.

In Bangladesh, there may be limited access to detailed and reliable accidents and incidents reports. Incomplete or inconsistent data can hinder the accurate application of HFACS and limit the insights gained from the analysis. The study's use of accidents/incidents reports to gather data on latent mistakes (Levels 4 and 3 of the HFACS framework) is one of its

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shortcomings. As a result, we were unable to investigate the connection between the HFACS framework's higher levels (Levels 4 and 3) and lower levels (Levels 1 and 2). Another research limitation is the absence of cockpit voice recorders (CVR) and flight data recorders (FDR) on commercial aircraft, which provide crucial data on human-machine interaction. This makes it impossible to conduct a more general, less detailed investigation of incidents involving instructional flights. The aviation regulatory framework and safety standards in Bangladesh may differ from those in other countries where HFACS has been extensively validated. Differences in regulatory oversight, enforcement and safety culture can affect how human errors are manifested and reported. The HFACS framework was developed primarily based on aviation data from other regions. Adapting this model to the Bangladeshi aviation context may require adjustments to better address local specificities, which could complicate the analysis. The context of Bangladesh’s successful aviation market and the major safety challenges brought about by growing traffic and operational complexity and despite technology and regulation at an all-time high, 80% of aviation accidents worldwide are still attributed to human error. HFACS to systematically examine human error patterns in Bangladeshi commercial aviation accidents/incidents, in terms of phases of flight (i.e. taxi, take-off, cruise, approach/landing and landing rollout). This study attempts to establish these errors, describe their effects on the severity of accidents and propose changes in safety practices. Challenges include data limitations and adapting HFACS to the regional context.

Review of Literature: This part delivers an indication of contemporary human factors studies on surface vessels, human error, accident causation and the HFACS. It includes a review of human issues concerns, the role of human error as a causative element (particularly in safety and aircraft accidents) and insights from prominent authorities in the field of human error. The examined literature comprises government-published studies, books by leading authors on human error and research papers from dissertations. An in-depth review of the HFACS taxonomy was conducted to offer an extensive understanding of the method.

HFACS Framework: It is widely recognized that aircraft accidents, like most other accidents, do not happen in isolation. Instead, they are often the result of a series of events that typically culminate in a hazardous action by the aircrew. Reason's (1990) concept of active and latent failures, as part of his “Swiss cheese” model of human error, has become the most widely accepted sequential theory for understanding accident causation. This theory builds upon earlier ideas, such as Heinrich's (1980) principles of industrial safety. Reason identifies four stages of human failure in his model, with each stage having an impact on the preceding one organizational influence, unsafe supervision, preconditions for unsafe acts, unsafe acts. The concept of active and latent failures is best visualized through Reason's Swiss Cheese Model, as shown in **Fig 1**, it did not deliver the level of detail needed for practical application in today's context [12].

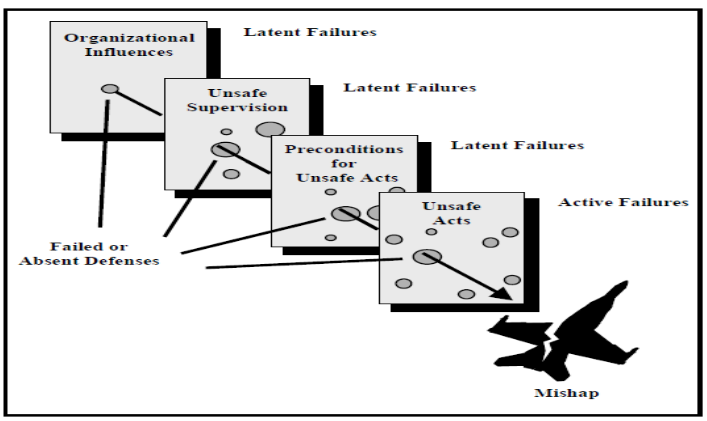

Fig. 1: The Swiss Cheese Model of accident causation of Reason’s representing how latent and active failures co-exist to violate several levels of defense.

It was not until Dr. Scott Shappell and Dr. Doug Wiegmann (2000, 2001) developed HFACS shown in **Fig 2** [12], a comprehensive framework for human error, that Reason's concept was applied. The U.S. Navy initially used this extensive human error framework to study and address human factors-related issues in aviation. Reason's (1990) four levels of human failure are divided into 19 causal categories in the HFACS framework. Unfortunately, this brief paper is not equipped to provide a detailed overview of all 19 causal categories. However, this information may be found elsewhere (Wiegmann and Shappell, 2003). The HFACS framework aids in the investigative process and provides a tool to focus training and preventative initiatives. Investigators can systematically identify the latent and active flaws within an organization that contributed to an accident. Instead of placing blame, the main goal of HFACS is to understand the root causes of accidents/incidents.

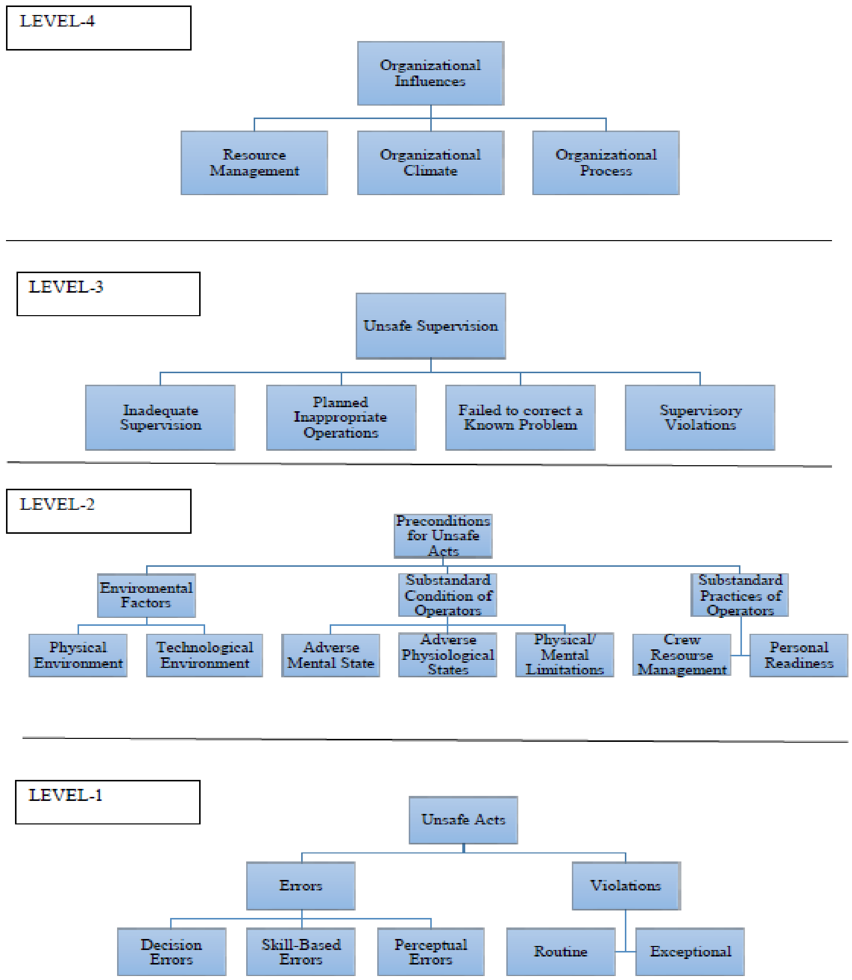

Fig. 2: The framework of Human Factors Analysis and Classification System (HFACS), which depicts the four levels of human failure and their subcategories.

Level 1: Unsafe Acts: The level of Unsafe Acts divided into two categories: errors and violations [12]. These categories are further divided into smaller subcategories:

a. Unintended behavior is called errors.

b. A violation is the deliberate disregard of the rules and regulations.

Errors

Skill-Based Errors: Errors that happen when an operator carries out a well-practiced, routine task involving procedure, training or skill, which results in a hazardous situation (e.g., checklist mistake, ingrained habits, failure to prioritize attention).

Decision Errors: The types of errors that happen when an operator's actions proceed as an objective, is selected approach is inadequate to reach the desired outcome, leading to a hazardous situation (e.g., exceeding capability, rule-based mistake, incorrect technique).

Perceptual Errors: These refer to errors made when a decision is based on incorrect information and the operator's perception is compromised.

Violations

Routine Violations: Conduct violations that the operator commits on an ongoing basis and that the regulatory body approves [12].

Exceptional Violations: They are specific violations of authority that are not common to those responsible for them [12].

Level 2: Preconditions for Unsafe Acts
Prerequisites for the Unsafe Act level are separated into three categories:

i. Environmental factors.

ii. Condition of operators.

iii. Personnel factors.

There are different subcategories within these three categories. The physical and technical elements that influence people's behaviors, circumstances and behaviors and lead to human errors or dangerous situations are referred to as environmental factors. The term condition of operators refers to adverse mental and physical conditions states as well as any physical or mental constraints that influence people's behaviors, circumstances or actions and lead to human errors. The crew resource management and personal preparedness elements that impact individual behaviors, situations or actions that lead to human errors are referred to as personnel factors [12].

Environmental Factors

Physical Environment: Describes factors like the surrounding environment (temperature, shaking, illumination, toxins) and the operating setting (weather, altitude, terrain).

Technological Environment: This element encompasses a range of design and automation concerns, including as equipment and control design, interface and display features, checklist layouts, task factors and automation.

Condition of Operators

Adverse Mental State: Adverse mental status refers to different factors such as psychological problems that impair motivation, stress or depression.

Adverse Physiological State: This term describes elements such as physical exhaustion, hypoxia, and medical illnesses that impact performance.

Physical/Mental Limitations: This states situations in which an operator's performance is impacted by a lack of mental or physical capacity to handle a situation (e.g., vision limits, insufficient response time).

Personnel Factors

Crew Resource Management: This involves tasks with collaboration, planning, coordination, and communication.

Personal Readiness: Specifies off-duty tasks necessary to perform optimally at work, such as following crew rest guidelines, liquor limits and other off duty instructions.

Level 3: Unsafe Supervision

The Unsafe Supervision level is categorized into four sections-

Inadequate Supervision: A supervisor's role is to provide their employees the best chance for success. To do this, they must offer direction, instruction, leadership, supervision, or rewards to guarantee that the work is done safely and effectively.

Plan Inappropriate Operation: This category includes operations such as risk management, crew pairing and operational tempo, that may be appropriate and different in emergency situations but inappropriate in regular operations.

Fail to Correct Known Problem: It defines situations where the supervisor is aware of errors but allows them to continue unchecked (e.g., report dangerous tendencies, start remedial action, address a safety hazard).

Supervisory Violations: The term supervisory violation highlights situations where supervisors knowingly ignore established rules and lexicons (e.g., enforcement of rules and regulations, unauthorized hazard, inadequate documentation).

Level 4: Organizational Influences

Organizational Influences levels are divided into three categories-

Resource Management: Resource management encompasses the processes and choices made at the corporate level as they relate to personnel, monetary and budgetary, and equipment and facilities along with other resources allocation and management.

Organizational Climate: Describes the structure of the environment in which people work within an organization, including policies and culture.

Operational Process: The organizational choices and terminology that govern day-to-day activities within an organization are referred to as operational processes (e.g., operations, procedures, supervision).

Perspective of Factors Affecting Human Errors in The Aviation Sector: A conceptual foundation for comprehending how people interact with different aspects of their work environment was offered by fundamental ideas in human factors. In this

Advisory Circular, some of the more prevalent aspects influencing human performance are briefly discussed. Normal, healthy, competent, experienced and highly driven employees make mistakes (and even infractions) in the working environment created by these elements [15]. These elements can all have an impact on human performance in an aviation setting, and they are often divided into three categories: those that are mostly personal, those that have an impact on how an individual interacts with others and those that have to do with the workplace. Personal traits and abilities Individuals differ in their abilities and performance. Individual performance under comparable operational conditions varies greatly. These variations can be observed by contrasting an individual's performance with that of others as well as by comparing the performance of people at various points in time. Below are a few instances

Anthropometry: Performance may be limited by physical attributes including height and weight, strength and reach and visual and auditory acuity. Thankfully, they largely stay the same over time and people learn to manage their physical characteristics. There are globally recognized norms and standards that may be used in the design of work stations, the hiring of staff and routine physical examinations [15].

Health and Performance: Some mild pathological diseases may go unnoticed, even by the individual afflicted. For example, gastrointestinal problems and heart attacks have led to unexpected incapacitation of air traffic controllers and pilots and in rare instances have contributed to accidents [15]. Mental health and performance may be directly correlated with physical fitness. Increased self-esteem and a decrease in stress and anxiety are two benefits of improved fitness. It is thought to improve resilience to tiredness and has positive effects on emotions, which influence motivation. Exercise, nutrition, stress levels, and usage of drugs, alcohol or tobacco can all have an impact on fitness.

Habituation: Human conduct is mostly automatic. Because we have mastered certain reactions to certain circumstances, we don't give it much thought. An example of a culturally influenced behavior is driving on either the left or right side of the road. Other reactions, like wearing a wedding band are the result of habituation, when we become accustomed to certain circumstances and eventually become unaware of them. A helpful strategy for effectively handling routine, recurring events is habituation. However, we could revert to a previously appropriate style of conduct while under stress, which could lead to mistakes. We may sometimes overlook potentially harmful signs due to habit [15].

Detection and Perception: Research has shown that there are measurable thresholds for identifying certain stimuli with our five senses and the number of different levels of a given stimulus that healthy humans can reliably distinguish. Technically, our eyes or ears can detect a certain input, but our brains cannot interpret the information and record the impression. Our capacity to notice stimuli may be hampered by several things, including noise or distractions, boredom or exhaustion, workload or other stressors. In jobs that need a high level of attentiveness, this distinction between detection and perception is crucial [15].

Stress: There are a lot of possible stresses in the aviation industry. The environmental stressors that flight crews were concerned about the early stages of aviation were mostly physiological and included noise, vibration, temperature, humidity, and acceleration forces. These days, these include things like erratic work and sleep schedules and disrupted circadian rhythms brought on by long-distance, irregular, or nighttime flight [15].

People react to stress in very different ways. For instance, flying during a thunderstorm may be difficult for some people but extremely traumatic for others. It is possible to forecast the impact of a certain stressor in certain ways. Experience and training can assist people in overcoming certain work-related stressors, such as completing a challenging task in challenging circumstances. Changing one's lifestyle can help decrease or even eliminate other pressures. Disruption of the body's rhythm [15].

Fatigue: While sleep deprivation is often mentioned as a primary cause of fatigue, other factors such as personal stress, lack of sleep and disruptions to the body's natural rhythms can also contribute. Intense tiredness may occur after long shifts or a series of demanding tasks completed in a short period. Over time, the buildup of fatigue can result in chronic tiredness. Even with adequate physical rest, emotional stress can cause mental fatigue. Similar to disruptions in bodily rhythms, fatigue can create dangerous situations and negatively affect both health and performance. Additionally, factors such as low oxygen levels and noise can exacerbate fatigue [15]. Although there is currently no direct method of measuring exhaustion (such as a blood test), it is possible to assess its consequences. The error rate rises with weariness when mistakes are quantified in terms of time. Whatever the reason, weariness tends to impair response and judgment, lead to a predisposition to accept lower operational performance requirements, produce computation mistakes and cause loss or erroneous remembering of recent events [15].

Personality and Attitudes: Our behavior at work and at home is influenced by our attitudes and personality features. Personality qualities can be learned early in life or are intrinsic. They are ingrained traits that characterize an individual and are both constant and unalterable. Aggression, ambition, and dominance are examples of traits that may represent personality [15]. People who were capable of doing well but chose not to do so have caused accidents due to their poor performance. The idea that attitudes and conduct have a big impact on in-flight safety is supported by reports from a number of secret aviation reporting programs. Deeply ingrained psychological traits are linked to some risky conduct [15]. Since it is impractical to expect impersonality to alter via training, the distinction between personality and attitudes is important. Personality difficulties should be addressed during the first round of screening and selection. Conversely, training has a greater ability to alter attitudes [15].

Communication: Communication errors in aviation can lead to serious safety risks by causing misunderstandings between pilots, air traffic controllers, and ground staff. These errors may result in incorrect flight instructions, runway incursions, or delays in critical decision-making, ultimately reducing situational awareness. In high-pressure environments, even small miscommunications can escalate into major accidents, making clear and accurate communication essential for safe flight operations [15]. Understanding common communication issues and enforcing language standards to guarantee error-free transmission and accurate message interpretation can help reduce communication errors. Additional information about individual aircraft and fewer aircraft separations means fewer delays when interacting with aircraft [15].

Workload: The quantity of work that is required of a person is referred to as their workload. Workload in aviation often refers to cerebral exertion rather than physical effort. Performance will decline if a job or series of tasks creates more work than a person can handle mentally. In general, experience and training prepare us to handle growing workloads efficiently. People may miss stages in their safe work routines or even ignore clear signs of harmful situations in an attempt to cope with stress [15].

Training and Evaluation: Here, training and education are viewed as two distinct facets of the learning process. Knowledge, values, attitudes, and fundamental skills are all part of education, which serves as a foundation for eventual development of more specialized talents. The process of developing certain abilities, information, or dispositions for a task or employment is called training. Without the foundations for the development of certain abilities, information, or attitudes being established by prior education, proper and effective training cannot occur. It is frequently possible to apply abilities, information, or dispositions acquired in one situation to another [15]. Training is the process of controlling the internal process of learning. The changes in performance or behavior that the learning results in must be used to judge whether the training was successful or not. The staffs must be an active participant rather than a passive one as learning is done by the staffs, not the instructor. Learning is related to memory. Information that will be momentarily retained and quickly forgotten is referred to as short-term memory (STM), but information that will be stored for a long time is referred to as long-term memory (LTM). STM can only process a small number of data points in a few seconds. Information is transmitted into LTM by repetition. Although LTM has a relatively big capacity and less storage issues, retrieval issues do exist, as demonstrated by the issues with witness recalls of previous occurrences [15].

Visual Performance and Collision Avoidance: Determining the ideal working environment requires a thorough grasp of how the visual system functions. In this field, light properties and measurements, color perception and human physiology are all pertinent. The capacity to recognize objects in the presence of rain or other contaminants on the windscreen, as well as the ability to detect airplanes at a distance, both during the day and at night, are also crucial [15].

Annex 13:

Investigation of Aviation Accidents and Incidents: Annex 13 of the Convention on International Civil Aviation clearly defines the term "accident" in the context of aviation. According to Annex 13, an aviation accident refers to any event involving the operation of an aircraft that occurs between the time a person boards with the intention of flight and when all passengers have disembarked or the aircraft has landed. This includes instances where the aircraft suffers significant damage or structural failure, someone is killed or seriously injured, the aircraft is lost or it becomes completely inoperable. Any event affecting operational safety that does not meet these criteria is classified as an incident, rather than an accident [16].

Background and Motivation: The study of aviation accidents and risks is faced with a number of new challenges due to the increasing complexity and diversity of modern accidents and incidents. Bangladesh is no different than the rest of the world. Independent Bangladesh had its first ever civil flight on 1 January 1972 with a Cessna 150 aircraft taking off from Tejgaon Airport [17]. On the other hand, according to the Aviation Safety Network database, the first reported accident was on 10 February 1972. This was a Biman Bangladesh Airlines Douglas DC-3, which crashed close to Dhaka, resulting in the demise of all 5 people on board [18]. Since then, there have been a number of accidents and incidents both at home and abroad for local airlines, including foreign airlines on home soil as well. The purpose of this study is to provide a brief outlook of the official civil aviation accident and incident reports of Bangladesh. By reviewing these reports, this paper aims to provide a stepping stone for future research ideas for the advancement and innovation of civil aviation risk analysis methodologies from Bangladesh's context. This brief review is not to find fault or ascribe blame for any aircraft accident or incident but rather to provide a means for the industry concerns, such as - pilots, aircraft producers and regulatory bodies, to acquire an understanding of corresponding occurrences.

Standards and Regulations: The CAAB is in charge of monitoring all activities related to civil aviation in the country of Bangladesh which is a part of the Ministry of Civil Aviation & Tourism. They also conduct international and domestic airport management, which also functions as a regulator to ensure that the provisions of the International Civil Aviation Organization (ICAO), as well as any other legally binding rules of the government of Bangladesh, are being met. As the aeronautical authority of Bangladeshi, CAAB performs the duties assigned to it by ICAO, which is governed also by the Civil Aviation Ordinance Act of 1960 and the Civil Aviation Rules Act of 1984 [19]. Likewise, in accordance with the provisions of the Chicago Convention and its articles, the ICAO has established 19 annexes to International Civil Aviation that contains a whole range of Set Standards and Recommended Practices. The People's republic of Bangladesh as one of the ICAO members and also a signatory of the Convention on International Civil Aviation is required to ensure that certain measures such as, safety, accident investigation and accident prevention are carried out and observed within the country. To fulfill these requirements, PART-C: Air Navigation Order (Aircraft Accident and Incident Investigation) outlines the necessary legal guidelines for preventing accidents and making safety recommendations in accordance with ICAO standards [9]. The Aviation Accident Investigation Committee-Bangladesh (AAIC-BD) was formed to handle notifications of accidents and incidents. An investigator is available around the clock to respond to any accidents or incidents involving civil aircraft operating outside of Bangladesh, as well as those operated by Bangladeshi operators [14].

Materials and Method

This section includes the research methodology in details.

Research Design: The accidents of commercial aviation will be researched by using the HFACS framework and looking at accident reports retrospectively. This will be a mixed-methods study, combining frequency counts of errors with a qualitative and quantitative analysis of error types.

Data collection: Primary data source taken from relevant interviews of the distinguished aviation experts. And secondary data sources have been collected from the recognized airlines of Bangladesh, journals of aviation, articles on aviation management, data of ICAO and IATA, relevant ANNEXES of ICAO and the Aircraft Accident Investigation Committee of Bangladesh (AAIC-BD), which is under CAAB.

Collect Primary and Secondary Data: Primary data is gathered through interviews with pilots, while secondary data is obtained from various journals, websites, literature, aviation and airline-related research papers and online resources about aviation.

An Overview of Accident and Incident Reports (Bangladesh Perspective): This paper reviews the following 17 official aircraft accident/incident reports investigated by AAIC-BD which are publicly listed on CAAB's website [14]. The gathered data are tabulated accordingly and represented through an array of graphs, figures and tables. The complete dataset of 17 accidents/incidents analyzed in this study is presented in Table 1, which recapitulates the individual accident information gathered based on their date and place of occurrence, along with their corresponding call sign spanning from 2015 to 2022. Amongst these accidents/incidents, 2 of them transpired on foreign soil (Nepal and Myanmar). The remaining 15 took place in various parts of Bangladesh, including Rajshahi, Chattogram, Cox's Bazar, Pabna, Jessore, Saidpur and Dhaka. Subsequently, depicts the relative representation of the type aircraft for the concurrent accidents/incidents from Fig 1. It can be perceived that, 4 out of the 17 accidents/incidents were rotary-wing aircraft and the remaining 13 were fixed wing aircraft.

Data Coding and Analysis Procedure: The categorization of the HFACS to every accident was carried out in a sequential manner. To start with, the first author examined every report of the AAIC-BD and determined the main and supplementary causal variables. The factors were then plotted against the corresponding level and category of HFACS according to the definitions that Wiegmann and Shappell (2003) provide. In a bid to increase reliability, a second aviation professional had a chance to review five accident reports randomly. Agreements on any differences in coding were reached through consensus. Such a procedure guaranteed the stability and reproducibility of the HFACS framework to the data.

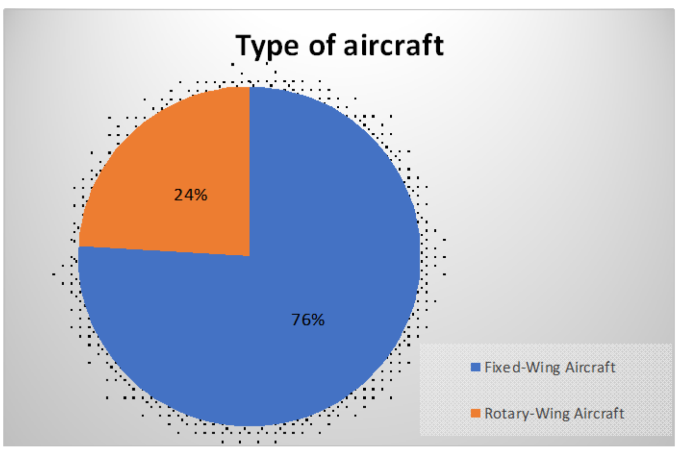

Fig. 3: Distribution of fixed-wing versus rotary-wing aircraft involved in the analyzed accidents and incidents 2015 to 2022.

Table 1. Comprehensive list of 17 aircraft accidents/incidents examined by AAIC-BD (2015-2022), date, venue, aircraft call sign, cause and HFACS classification.

No.	Date of Accident/Incident	Aircraft Call Sign	Place of Occurrence	Cause of Accident	Remarks
1	1-Apr-15	S2-ADI	Shah Makhdum Airport, Rajshahi, Bangladesh	a) The accident had occurred due to an unauthorized exercise undertaken to demonstrate PFL from a very low altitude and close downwind position. b) A go-around or discontinuation was not possible due to a probable unauthorized engine shut down on the downwind position.	(1) Exceptional Violations. (3) Planned inappropriate Operations.
2	9-Mar-16	S2-AGZ	Hazrat Shah Amanat International Airport, Chittagong, Bangladesh	a) Failure to initiate a rejected take off during take-off roll following the indication of engine failure; b) Failure to adhere to the company SOP following the detection of the engine failure during take-off; c) Considering the poor visibility at Cox's Bazar Airport, diverting to the alternate airfield Chittagong Airport located only 50 nm away that has the provision for full ILS approach facility. This could have helped the crew in carrying out a proper one engine out precision approach landing; d) The aircraft flew at a speed much lower than the clean configuration speed. The aircraft flew at 225 km/h in clean e) configuration whereas the minimum clean configuration speed is 290 km/hr. f) As per the FDR data the aircraft stalled while making a turn towards the side of the failed engine at a very low altitude.	(1) Decision Errors (1) Skill-Based Errors (1) Perceptual Errors (2) Adverse Mental State
3	7-Jun-16	S2-AFP	Hazrat Shah Jalal International Airport, Dhaka, Bangladesh	a) The analysis of the engine condition trend monitoring data, being stable and similar to the sister engine, did not show any trend shifts or fluctuations prior to the attempted event flight on June 7th 2016. According to the operator's information, no relevant faults existed on the aircraft or engine systems. Also, the maintenance records did not show relevant entries for the subject engine.	Technical / Maintenance
4	16-Sep-16	S2-AIB	Inani Beach, Cox's Bazar, Bangladesh	a) The front seat passenger interfered with the helicopter Cyclic Control endangering the flight performance. b) A sudden jerk by the front seated passenger to the helicopter Cyclic Control while the helicopter was at a very low altitude just before landing attributed the accident.	(2) Physical Environment
5	1-Oct-17	S2-AGT	Chatmohar, Pabna, Bangladesh	a) The main cause of the accident was Dynamic Rollover during a hurried landing.	(1) Decision Errors (1) Skill-Based Errors
6	16-Jan-18	S2-AAX	Jessore Airport, Bangladesh	a) Metal fatigue leading to the breakage and dislocation of the hydraulic fitting that gave rise to loss of hydraulic fluid resulting the loss of steering wheel control and braking during taxing of the aircraft.	(2) Technological Environment
7	12-Mar-18	S2-AGU	Tribhuvan International Airport, Kathmandu, Nepal	a) The Accident Investigation Commission determines that the probable cause of the accident is due to disorientation and a complete loss of situational awareness in the part of crewmember. Contributing to this the aircraft was offset to the proper approach path that led to maneuvers in a very dangerous and unsafe attitude to align with the runway. Landing was completed in a sheer desperation after sighting the runway, at very close proximity and very low altitude. There was no attempt made to carry out a go around, when a go around seemed possible until the last instant before touchdown on the runway.	(2) Adverse Mental State (1) Decision Errors
8	24-Jul-18	HS-TJD	Hazrat Shah Jalal International Airport, Dhaka, Bangladesh	The cause of the serious incident was due to **'Human Factor'**, wherein, a) The flight crew's inadequate coordination during manual handling of the aircraft while approach to land resulted the aircraft neither touch down within the „touchdown zone" nor at or close to the centerline of the RWY due to inappropriate alignment with the RWY; and, b) According to the DFDR read out, the PIC applied the left rudder immediately after touch down to bring the aircraft back to centerline. The PIC provided left rudder input for a duration of approximately 19.6s, reaching a peak recorded value of 25.7679 inches (left	(1) Skill-Based Errors

				rudder pedal forward). However, either, the left rudder pedal input was insufficient or, there were requirement to use left wheel brakes also (which was not applied initially) to prevent the aircraft from veering off the right edge of the runway due to inertia.	
9	26-Sep-18	S2-AJA	Shah Amanat International Airport, Chattagram, Bangladesh	a) Failure of the Nose Landing Gear Retract Pressure Fuse PIN 2-8020-6, SIN 0959 that prevented the Nose Landing Gear not to extend.	Technical
10	11-Oct-18	S2-AHW	Godagari (under Rajshahi District), Bangladesh	a) Suspected engine failure.	Technical / Maintenance
11	8-May-19	S2-AGQ	Yangon International Airport, Myanmar (Burma)	a) While the aircraft was unestablished on approach, the pilot did not execute a go-around.	(1) Decision Errors
12	8-Oct-20	S2-ADQ	Shah Makhdum Airport, Rajshahi, Bangladesh	a) The main cause of this serious incident was 'Human Factor' wherein; the Student Pilot was not able to proficiently man oeuvre the aircraft during taxiing inside the dumbbell area using proper speed-control, asymmetric brake, and rudder paddle in a coordinated manner. b) The Student Pilot was not subjected to proper training/practice on taxiing, braking and rudder application. c) The Instructor Pilot demonstrated tangible lack of Instructional Technique and monitoring the level of proficiency of Student Pilot's, especially in 'taxiing' the aircraft.	(1) Skill-Based Errors
13	9-Jan-21	S2-AFK	Shah Makhdum Airport Rajshahi, Bangladesh	a) Faulty handling of the aircraft by the flight crew following flare out and landing.	(1) Skill-Based Errors
14	16-Mar-21	S2-AGG	Lalpur, Tanore Upazilla 11 NM North West of VGRJ Airport, Rajshahi Bangladesh	a) The accident took place due to engine failure in the air. On the basis of evidences found during test and research, the AAIT is in the opinion that the causes of the engine failure were due to damaged, partial damaged, broken or worn-out of some internal parts in one, more or in all cylinders that allowed the cylinder pressure to leak and caused the engine oil to drain through vent/ breather-line or other points. b) However, this can be ascertained after carrying out the tear-down investigation at manufacturer's facilities and if new outcome, will be mentioned in the re-opened investigation report.	None above
15	17-Nov-21	S2-AHF	Airport, Saidpur, Bangladesh	a) The main cause of this serious incident was 'Environmental Factor' wherein; eventual loss of median torque link 'PIN' (Part No D64724) due to the corrosion of the thread of the PIN, b) Probably the 'Nut' (Part No. SL40358P, not found) causing the loosening of the nut leading to the loss of steering function, c) Material loss due to corrosion was responsible for thread contour failing, this falling result in increased load on the remaining threads leading to their deformation and allowing the nut to become detached from the PIN.	Technical / Maintenance
16	5-Jun-22	S2-AHI	Shah Amanat International Airport, Chattogram, Bangladesh	a) The detachment of the outer (No.1) wheel assembly from the wheel axle was the causal factor for this serious incident, which took place after take-off from VGEG at 0535 UTC on 05 June 2022. b) The root cause of the incident was the outer bearing failure which was induced due to severe static corrosion.	Technical / Maintenance
17	21-Oct-22	S2-AJD	Hazrat Shahjalal International Airport, Dhaka, Bangladesh	a) All the seven bolts were broken due to fatigue failure. The fracture surface of the tie-bolt indicated multi-origin high-cycle fatigue, with the ductile separation at final rupture. High-cycle fatigue was determined to be the primary fracture mode of the broken bolts.	(3)Inadequate Supervision

Here, rather lucidly visible, the maximum number of accidents occurred in the year 2018 within the considered period. To achieve a distinct understanding, for each accidents and incidents, a year-wise passenger and flight condition data is shown in **Table 2** [14]. Comparatively, 2018 had the highest number of fatalities in a single year, with the tally coming to a total of 51. From the year 2015 to 2022, it is discerned that, officially, there have been 56 injuries and 55 deaths with regard to Bangladesh's aviation accidents.

Table 2. Annual summary of passenger casualties and flight safety outcomes for aviation accidents/incidents in Bangladesh (2015-2022).

Year	Passengers Condition		Flight Condition	
	Injured	Death	Fatal	Non-fatal
2015	1	1	1	0
2016	5	3	2	1
2017	0	0	0	1
2018	29	51	1	4
2019	20	0	0	1
2020	0	0	0	1
2021	1	0	0	3
2022	0	0	0	2
Total	56	55	4	13

In **Fig. 2** outlines the year-wise injuries and death counts 2018 saw the highest number of passengers fatalities with 51 and 29 seriously injured, followed by 2016 with 3 fatalities and 5 injuries and 2015 with one fatality and one seriously injured. In 2019 and 2021, there were no fatalities but 20 people and 1 person injured.

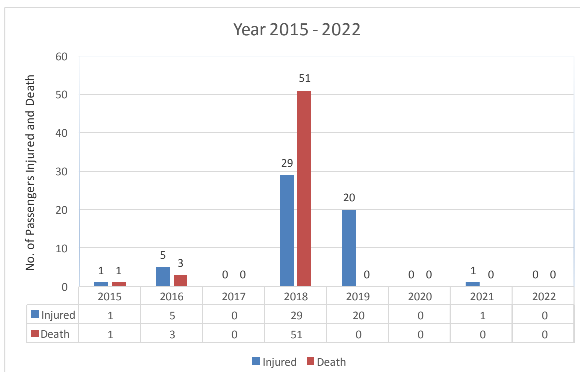

Fig. 4: Year wise number of passengers' injuries and death counts.

Where **Fig 3** outlines the year wise fatal and non-fatal flight accident counts, where it can be detected that during the 2015 - 2022 period, there has been a total of 4 fatal accidents out of the investigated 17. Of these fatalities, 1 transpired during the year 2015. Followed by 2 fatal accidents occurring in 2016 and 1 fatal befalling in 2018.

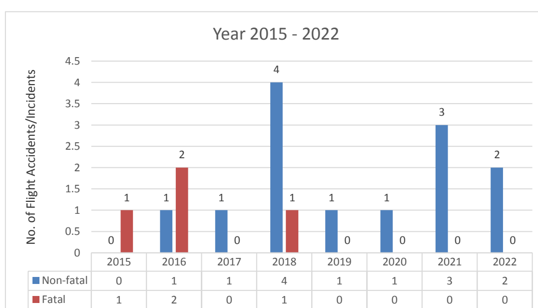

Fig. 5: Year wise fatal and non-fatal accidents/incidents in flight.

AAIC-BD has studied and collected the aviation accident report of 17 accidents/incidents from Bangladesh that occurred from 2015 to 2022. This report is intended to explain the policies in aviation safety that are directed toward the reduction or elimination of risk in air transportation. The other types of aviation accidents possible include: -

i. The Occurrence Type: Accident.

ii. Aviation Operation: Commercial.

iii. Flight Objective: Transport of Passengers and Cargo by Air.

iv. Aircraft Type: Airplane.

v. Report Status: Probable Reasons.

vi. Seriousness of Injury: Fatal and Non-Fatal.

The two classes of codes were defined as 0 for absent and 1 for present. There were no new developing contributing variables in the coding. In other words, the AAIC-BD contributed variables widely as the concerned elements. After the coding process, the encoded information was presented in Table 3.

Table 3. Table of frequency and percentage of **17** accidents/incidents by HFACS categories.

HFACS Category	Frequency	All accidents (%)
Decision Errors (1)	4	23.52
Skill-Based Errors (1)	5	29.41
Perceptual Errors (1)	1	5.88
Routine Violations (1)	0	0
Exceptional Violations (1)	1	5.88
Physical Environment (2)	1	5.88
Technological Environment (2)	1	5.88
Adverse Mental State (2)	2	11.76
Adverse Physiological State (2)	0	0
Physical/Mental Limitations (2)	0	0
Crew Resource Management (CRM) (2)	0	0
Personal Readiness (2)	0	0
Inadequate Supervision (3)	1	5.88
Planned Inappropriate Operations (3)	1	5.88
Failed to correct a known problem (3)	0	0
Supervisory Violations (3)	0	0
Resource Management (4)	0	0
Organizational Climate (4)	0	0
Organizational Process (4)	0	0
Total	**17**	

Note: The HFACS framework's respected levels for each HFACS category are shown by the numbers.

An analysis of Table 3 reveals that which shown in Fig 4 illustrates the proportion of causative elements associated with each level of the HFACS framework. A deeper look at the data shows that ‘preconditions for unsafe acts’ are notably common, accounting for 23%. Unsafe acts were associated with 65% of the highest number of accidents. To our surprise, both the final reports and probable cause reports of relatively low chances of flight accidents were associated with unsafe supervision and organizational influences.

Configuration of Four Levels by Human Error

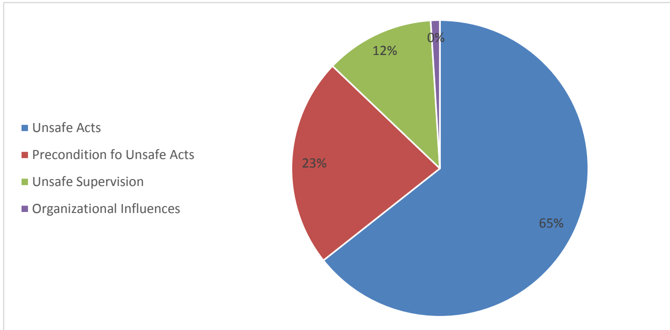

Fig. 6: The percentage of contributing elements based on the HFACS frameworks with four categories.

Accidents by Flight Phases

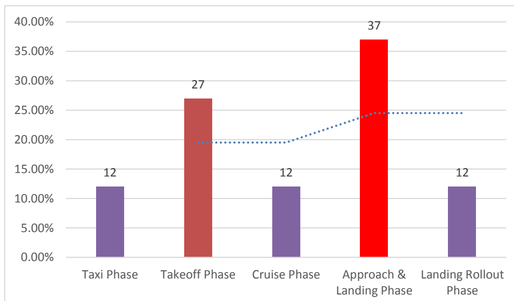

Fig. 7: The percentage of accidents flight phases through the HFACS frameworks of four levels.

It is often recognized that in both commercial and general aviation, the takeoff and approach/landing are the most crucial flight phases for accidents. Pilots are particularly busy during flights with several critical duties such as communicating with ATC and managing the flight path during the final approach/landing phase. In alignment with earlier research, our analysis revealed that the approach/landing phase accounted for the highest number of accidents reached to 37%, followed by 27% during the takeoff phase. Meanwhile, 12% of accidents occurred in the taxi, cruise and landing rollout phases, respectively shown in fig 5.

Results and Discussion: After reviewing the data in Table 1 of Chapter 3, the contributing variables behind the 17 aircraft accidents/incidents were classified, resulting in 17 category assignments. Following the analysis, the statistics were presented in Table 3 of Chapter 3. The values for each level of HFACS, calculated separately for the 17 aircraft accidents, are graphically shown in Fig 4 and Fig 5 of Chapter 3. A detailed examination of the contributing factors in 17 aircraft accidents/incidents was conducted to gain a deeper understanding of the actual hazards involved. This section will cover the causal categories associated with each level of the HFACS framework.

Table 3 of Chapter 3, showed that skill-based errors were the most significant contributing factors. These findings are consistent with earlier research. Accidents across various types of operations in commercial airlines were predominantly caused by skill-based errors. Pilot training is undoubtedly the cornerstone of the entire aviation sector. Therefore, in order to avoid difficulty, pilots should focus on basic flying abilities from the start and avoid a lack of knowledge or competence (e.g., crosswind takeoff and landing methods). Also, my observations indicate that taxi, takeoff, cruise, approach/landing and landing rollout have the highest chance of accidents during approach/landing. From the graph in figure 5 of Chapter 3, it can be seen that the highest chance of accident occurs during approach/landing with a percentage of 37%. In the next phase, there is a chance of an accident at takeoff, the percentage of which is 27%. Taxi, cruise and landing rollout has the lowest chance of accident with almost the same percentages such as 12%. Analysis of the graph in figure 5 of Chapter 3 shows that the five flight phases have the highest contribution to accidents due to decision errors and skill-based errors.

Conclusions: The quality of this work was that the Human Factors Analysis and Classification System (HFACS) has been effectively used in the context of analyzing 17 commercial aviation incidents and accidents in Bangladesh that took place in 2015-2022. This is, as far as the authors know, the first systematic implementation of the HFACS framework to the Bangladeshi aviation context. The analysis has found that most of the contributing factors comprised of skill-based errors (29.41%), decision errors (23.52%), and more than fifty percent of all identified unsafe acts. Additionally, there was a considerable distribution of these errors over flight phases with the approach/landing stage and takeoff stage being the most critical phases (37% and 27% of accidents, respectively). These results coincide with the rest of the studies conducted on HFACS in the world, including Shappell et al. (2017) [3], who attest to the universality of skill-based and decision-making deficits in aviation safety. Nevertheless, it is clear that an absolute risk concentration at the stage of approach and landing in Bangladesh has highlighted a particular region that needs direct and immediate action. The limitations of the study are also recognized the use of official reports, which might not have the information about the latent organizational factors, and the absence of Flight Data Recorder (FDR) data to provide a more detailed analysis. On the basis of these findings some recommendations can be given in order to improve aviation safety in Bangladesh. Firstly, the basic and recurrent training should be reinforced, and special attention should be paid to the reduction of skill-based and decision errors in the high-risk stages. This will involve the training of the crosswind takeoffs and crosswind landings, unstable approach recovery, and mandatory go-around on the simulator. Aeronautical Decision-Making (ADM) and Crew Resource Management (CRM) also should be included in the training to enhance decision-making in the situation with high workload. Then, a greater degree of supervision should be adopted by the airlines and the Civil Aviation Authority of Bangladesh (CAAB). This involves increasing pre-flight and in-flight checklist checks and building of effective safety management systems (SMS) in order to conduct proactive checking of latent risks, including insufficient supervision and correction of known issues. Next, to overcome the failures related to the technological environment, the investments should be made to update the aircraft and introduce even stricter maintenance measures. The dependability of the avionics, landing gear, and engine system is important in ensuring that accidents caused due to technical failure, which is compounded by human factor, is avoided. After that, CAAB needs to keep on revising and strictly enforcing national aviation regulations and aligning them with International Civil Aviation Organization (ICAO) standards. This will assist in filling gaps in organizational climate and performance procedures that are capable of establishing preconditions of unsafe acts. Finally, adoption of ccontinuous monitoring and data-driven evaluation should be done through the establishment of a continuous monitoring system on the pilot proficiency, particularly on the critical takeoff and approach/landing procedures. Using data analysis and real-time analysis will be useful in ensuring that the level of skill remains stable and that risk trends are monitored before becoming the cause of accidents. Further studies are advised to be based on this framework to investigate the connection between various levels of the HFACS framework in the Bangladeshi context. The role of intangible latent failures, such as organizational and supervisory factors, should also be examined in the further studies, and interviews as well as surveys among the aviation professionals should be used. This will allow a more holistic view of the systemic factors of aviation accidents and will also inform the design of the effective safety interventions in the fast-growing aviation industry in Bangladesh.

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