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Evaluating Human Factors in the Commercial Pilot-Airplane Airman Certification Standards

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This research aimed to identify risk management elements in the Commercial Pilot-Airplane Airman Certification Standards (ACS) and evaluate tasks relating to or involving human factors. The investigation examined the risk management elements under each task in the Commercial Pilot-Airplane ACS and classified them under the preconditions for unsafe acts of the Human Factors Analysis Classification System (HFACS). The method of investigation was a qualitative research approach to determine the human factors element prevalent in the Commercial Pilot-Airplane ACS. Three research questions were stated: (1) Which factor under the preconditions for unsafe of HFACS has the highest number of tasks relating to or involving human factors? (2) Which risk management element is prevalent in the commercial airplane pilot ACS**?** (3) In order of priority, which risk elements need to be emphasized in the training programs? The data analysis and information synthesis were done to arrive at results, conclusions, and recommendations to improve the training program. The recommendations are: (1) Conduct adequate training in the use of aircraft systems and automation to enhance human performance and reduce workload, stress, fatigue, and human errors; (2) Include scenario-based training (SBT) in the training syllabus that will challenge pilots to improve decision-making that can mitigate the loss of situational awareness and lack of effective crew resources management; and (3) Incorporate team-building techniques into the training syllabus to enhance crew performance.

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1.1 Introduction

Over the past four decades, the leading cause of aviation accidents and incidents has been invariably linked to human factors (Munene, 2016). This problem has led to the Federal Aviation Administration (FAA) replacing the Practical Test Standards (PTS) for commercial pilots with the ACS (FAA, 2018b). Human error is found to be the most significant issue in flight operations and is implicated in almost all aviation accidents (Munene, 2016). In spite of improvements in technology, humans are responsible for ensuring the safety of flight (Wiegmann & Shappell, 2003).

Statistics reveal that approximately 80 percent of aviation accidents are attributable to human factors, which has made it an important topic to address in the industry (Munene, 2016). Wiegmann, Rich & Shappell (2000) further stated that "a growing number of aviation establishments are tasking their safety personnel with developing safety programs to address the highly complex and often nebulous issues of human error" (p. 1).

The FAA took a practical step to address safety concerns regarding human errors in the training environment by replacing the PTS for commercial pilots with ACS to communicate the aeronautical knowledge, risk management, and flight proficiency standards for pilots and to reduce human errors associated with flight operations (FAA, n.d). "The ACS is a portion of the safety management system (SMS) framework that the FAA uses to mitigate risks associated with airman certification training and testing" (FAA, 2018b, p. iii). It offers an all-inclusive and combined presentation of the standards that an applicant needs to successfully pass both the knowledge and practical tests for a certificate or rating (FAA, 2018b). However, the ACS has become a more useful tool than simply passing both knowledge and practical tests for a rating or certificate (FAA, n.d). It provides a framework to mitigate human errors that aviation organizations can adopt in the initial and recurrent training programs for company pilots (FAA, n.d).

As part of the efforts to mitigate human errors, the FAA highlights various risk elements associated with each task in the ACS to ensure pilots are conversant with factors that can serve as precursors to aircraft accidents and incidents (FAA, n.d). Understanding these risk elements can break the chain of errors leading to unsafe acts of the operator (Kanki, Anca, & Chidester, 2019). Therefore, this paper classifies these risk elements under the preconditions for unsafe acts in the taxonomy of HFACS.

2.1 Intent

This qualitative research aimed to evaluate the Commercial Pilot-Airplane ACS, focusing on the risk management elements of the tasks in the ACS to classify them under the preconditions for unsafe acts of the taxonomy of HFACS. Risk management is vital to successful and safe flight operations due to human errors identified in many aviation accidents (Munene, 2016). Therefore, the risk management elements in each task in the airman certification standards (ACS) were evaluated and classified using the preconditions for unsafe acts in Human Factors Analysis Classification System (HFACS) model. The Human Factors Analysis and Classification System (HFACS) is a tool to identify and classify human errors in complex systems (Small, 2020). As such, it can be thought of as a Human Factors Root Cause Analysis (RCA) tool. Thus, this research aimed to identify risk management elements in the ACS, classify them under the precondition for unsafe acts of HFACS, and identify the most frequent ones in the Commercial Pilot-Airplane ACS.

3.1 Research Questions

- Which factor under the preconditions for unsafe of HFACS has the highest number of tasks relating to or involving human factors?
- Which risk management elements are most frequent in the Commercial Pilot-Airplane ACS**?**

4.0 Literature Themes

4.1 The Airman Certification Standards

The airman certification standards (ACS) are an enhanced version of the Practical Test Standards (PTS), which includes task-specific knowledge and risk management elements for each area of operation and task (FAA, n.d). The purpose of developing ACS was to fix the airman knowledge tests since several knowledge test questions were considered overly broad, complex, trivial, outdated, and irrelevant to the knowledge and skill required to operate in the national airspace system (NAS) (FAA, n.d). The main cause of these problems was traced to the fact that the FAA knowledge test standard did not correspond to the PTS as a means to define the acceptable performance of the "flight proficiency" (skills) to earn an FAA airman certificate or rating (FAA, n.d). Therefore, the industry group suggested that the way to combat this problem would be to integrate aeronautical knowledge and risk management elements into the PTS Areas of Operation/Tasks to form airman certification standards (ACS) (FAA, n.d).

Even though the PTS was used to evaluate students' knowledge and risk management elements, the ACS has become an invaluable tool in flight training environments that clearly defines all the elements in the ACS and organizes them in the context of phases of flight (FAA, n.d). In addition, several modifications, such as the slow flight and stall’s area of operations, were also made in the Private Pilot and Commercial Pilot ACS to improve the safety of flight based on reports received from various incidents and accidents (FAA, n.d).

Although the FAA's objective was to address the lack of a knowledge test standard (KTS) corresponding to the Practical Test Standards (FAA, n.d), Rod Machado (2016) said the PTS should have been left untouchable by anyone wise enough to see its ultimate value. He further stated that the ACS is a modified PTS to accommodate the FAA's postmodern and fantasy-type thinking about risk management in flight training (Rod Machado, 2016). Regardless of Rod Machado's opinions about the ACS, The FAA believes “the PTS has long required evaluating knowledge and risk management elements in both the ground and flight portions of the practical test; however, the ACS provides a better tool because it clearly defines these elements and organizes them in the context of phases of flight” (FAA, n.d, p.7, para 1).

4.2 Human Factors Analysis Classification System

The HFACS is an effective framework within the military, commercial, and general aviation sectors primarily designed as an investigation and data analysis tool for the U.S. Navy and Marine Corps (Wiegmann, Faaborg, Boquet, Detwiler, Holcomb, & Shappell, 2005). Since its inception, it has been explored by other organizations, such as the FAA, to analyze the underlying causes of aircraft accidents and incidents and to improve investigations (Shappell & Wiegmann, 2001). Wiegmann, Faaborg, Boquet, Detwiler, Holcomb, & Shappell (2005) stated that HFACS is a theoretically based tool for investigating and analyzing human errors associated with accidents and incidents.

HFACS framework identifies situational factors, personnel factors, and the condition of the operators as the preconditions for unsafe acts. The preconditions for unsafe acts are used in analyzing causes and trends of human errors contributing to aircraft accidents (Small, 2020). Generally, errors are consequences of actions or inactions, reducing safety margins and leading to deviations from operational rules (Guastello, 2014), and as revealed by research, pilots' unsafe acts can be directly attributable to almost 80% of aviation mishaps (Munene, 2016). However, to enhance safety, attention should be focused on the causes of unsafe acts to provide ways to break a chain of errors leading to aircraft accidents and incidents (Shappell, Detwiler, Holcomb, Hackworth, Boquet, & Wiegmann, 2007).

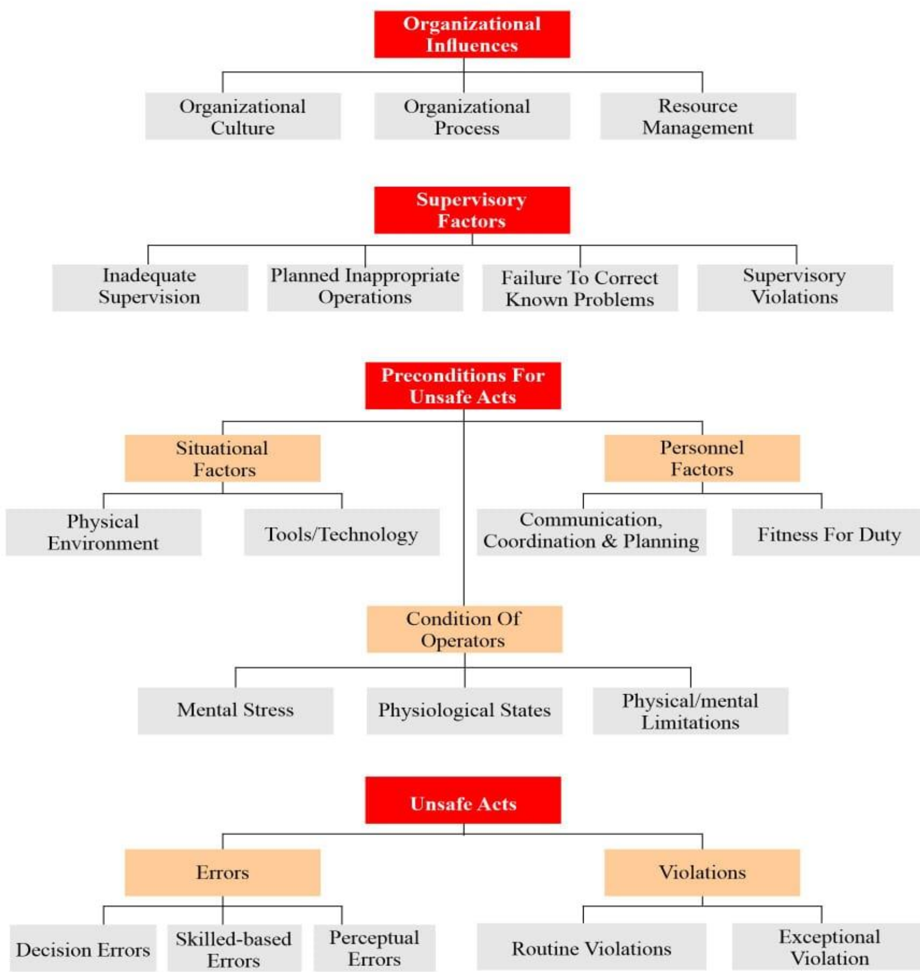

Figure 1: The HFACS framework. Designed by Wiegmann and Shappell (2000).

The precondition for unsafe acts is the third level of HFACS, and it's divided into three classifications: environmental factors, conditions of operators, and personal factors (Shappell & Wiegmann, 2000). Environmental factors comprise the physical and technological environments. The technology environment comprises a selection of issues, as well as the design of equipment and controls, display/interface characteristics, checklist layouts, task factors, and automation. The Physical environment comprises the operational setting, such as weather, altitude, terrain, and the ambient environment, such as heat, vibration, lighting, and toxins (Shappell, Detwiler, Holcomb, Hackworth, Boquet, & Wiegmann, 2007). These factors can contribute to or lead to errors committed by pilots (Shappell & Wiegmann, 2000). For instance, technology enhances pilots' workload when used properly (Small, 2020). However, the misuse of technology can cause more problems in flight, increasing the risk of unsafe acts (Small, 2020).

The condition of operators comprises adverse mental states, adverse physiological states, and physical or mental limitations that may serve as precursors of unsafe acts (Shappell & Wiegmann, 2000). Finally, personnel factors include personnel readiness, also regarded as fitness for duty, and factors pertaining to crew resources management such as communication, coordination, and planning (Shappell, Detwiler, Holcomb, Hackworth, Boquet, & Wiegmann, 2007).

The whole essence of incorporating risk management elements in the ACS was to prevent unsafe acts in the aviation industry, as nearly 80 percent of aviation accidents and incidents can be directly linked to unsafe acts (Shappell & Wiegmann, 2000). As earlier stated, the ACS provides a better tool for clearly defining risk management elements and organizing them in the context of phases of flight (FAA, n.d). When these risk factors are better understood, safety margin increases (Stolzer & Goglia, 2016).

Further inquiries into the causes of unsafe acts led to preconditions for unsafe acts, which are identified as situational factors, personnel factors, and the condition of the operators (Shappell & Wiegmann, 2000). The industry widely recognizes that a proper understanding of preconditions for unsafe acts will help airmen gain the necessary risk management skills to improve aviation safety and increase human factors awareness (Shappell & Wiegmann, 2000).

Human factors awareness enhances productivity and leads to an environment that ensures continuing worker and aircraft safety (FAA, 2018a). A human factors framework involves gathering information about human abilities, limitations, and other characteristics and applying it to tools, machines, systems, tasks, jobs, and environments to produce safe, comfortable, and effective human use (Zhang, 2008). Erjavac, Lammartino, & Fossaceca (2018) stated that "the HFACS is a tool applied to define a framework intended to recognize focal areas for the safety community to alleviate similar future system failures" (p.1). HFACS has been used to identify human errors in complex systems in many domains, and it provides a means of identifying causal pathways of failures within those systems (Shappell, Detwiler, Holcomb, Hackworth, Boquet, & Wiegmann, 2007).

5.1 Methodology

Qualitative approach was used in this research because it fits the research question properly and offers an adequate way to construct the required knowledge, and the data were derived from the Commercial Pilot ACS. In addition, the airman certification process aims to ensure each applicant possesses the knowledge, ability to manage risks, and skill consistent with the privileges of the certificate or rating being exercised to act as pilot-in-command (PIC) (FAA, 2018b). Therefore, the FAA highlights risk elements that should be well understood under each task in the ACS to prevent unsafe acts (FAA, 2018b).

The qualitative research design used in this study is a deductive coding analysis. The coding process involves initial coding and line-by-line coding. In the initial coding, the descriptive coding method was adopted to classify data derived from the ACS into three parts according to the three functional categories of preconditions for unsafe acts. The first description was labeled situational factor, the second was personnel factor, and the third was condition of the operator.

Going by the guidelines of HFACS. Tasks with risk elements associated with the physical environment, tools, and technology were labeled as situational factors. Tasks involving risk elements related to communication, coordination, planning, and fitness for duty were labeled as Personnel Factors. Finally, risk elements relating to the operator's mental state, physiological state, and physical and mental limitations were labeled as the condition of the operators.

The line-by-line coding is a very time consuming and tedious work, but at the same time, it also helps to build detail structured conceptual data model "(Khandkar, 2009). Line-by-line coding was used to group each task in the ACS under situational factors, personnel factors, or conditions of the operators.

6.1 Results

There are 60 tasks in the ACS. Ten tasks are unrelated to airplane single-engine and multi-engine land, leaving 50 tasks that could be classified under the preconditions for unsafe acts. The classification was done using deductive coding based on predominant risk elements in each task and test-retest reliability to ascertain the analysis of the results. The evaluation and classification of risk management elements of each task in the Commercial Pilot ACS showed that forty tasks have predominant risk elements relating to situational Factors, six tasks have predominant risk elements relating to Personnel Factors, and four tasks have predominant risk elements relating to the Condition of the Operators.

6. 2 Situational Factors

According to the HFACS, situational factors are directly related to the physical environment, tools, and technological environment. For this reason, forty of the tasks in the Commercial Pilot Airplane ACS were classified under situational factors. These tasks have risk elements associated with the physical environment, tools, and technological environment. The physical environment includes both operational settings and the ambient environment. Operational settings are factors such as weather, altitude, and terrain, and the ambient environment includes heat, vibration, lighting, and toxins. The technological environment encompasses a variety of issues, including the design of equipment and controls, display/interface characteristics, checklist layouts, task factors, and automation. For instance, the risk element under navigation systems and radar service stated that the applicant for a commercial pilot license demonstrates the ability to identify, assess and mitigate risks, encompassing the following:

- Failure to manage automated navigation and autoflight systems.

- Distractions, loss of situational awareness, or improper task management.

Table 1 shows the list of the tasks grouped under situational factors.

Table 1

Situational Factors		
• Airworthiness Requirements • Weather Information • Cross-country Flight Planning • National Airspace • Performance and Limitations • Operation of Systems • Preflight Assessment • Flight Deck Management • Engine Starting • Traffic Patterns • Normal Takeoff & Climb • Normal App & Landing • Soft-filed Takeoff and Climb • Soft-field App & Landing • Short-field Takeoff and Maximum Performance • Short-field App & Landing • Lost Procedures	• Go-around / Rejected Landings • Steep Turns • Steep Spiral • Chandelles • Lazy Eights • Eight on Pylons • Pilotage and Dead Reckoning • Navigation Systems and Radar Services • Maneuvering During Slow Flight • Power-off Stalls • Power-on Stalls • Accelerated Stalls • Spin Awareness	• Emergency Descent • Emergency App & Landing • System & Equipment Malfunctions • Engine Failure During Takeoff Before V_{MC} • Engine Failure after Liftoff • Approach & Landing with an Inoperative Engine • Maneuvering with One Engine Inoperative • V_{MC} Demonstration • One Engine Inoperative (Simulated Instrument) • Instrument Approach with an Inoperative Engine

6.3 Personnel Factor

Six out of the Commercial Pilot Airplane ACS tasks have predominant risk elements relating to personnel factors. Personnel factors include crew resources management (CRM) issues and personnel readiness. Crew resource management relates to communication, coordination, and teamwork issues that impact performance. Personnel readiness deals with off-duty activities needed to function optimally on the job, such as adhering to crew rest requirements, alcohol restrictions, and other off-duty mandates. For instance, the risk management elements for task D (taxiing) under preflight procedures state that the applicant demonstrates the ability to identify, assess and mitigate risks, encompassing:

- Inappropriate activities and distractions.
- Confirmation or expectation bias as related to taxi instructions.
- A taxi route or departure runway change.

Therefore, tasks that can lead to confirmation or expectation bias, division of attention while conducting pre-flight checks, poor communication, failure to utilize all available resources, and failure to record times over waypoints were classified under personnel factors. Table 2 shows the list of the tasks grouped under personnel factors.

Table 2

Personnel Factor	
• Pilot Qualification	• Communications, Light Signals, Runway Lighting
• Taxiing	• After Landing, Parking & Securing
• Before Takeoff Check	• Diversion

6.4 Condition of the Operator

The classification results revealed that four out of the Commercial Pilot Airplane ACS tasks have predominant risk elements relating to the condition of the operation. The operator's condition deals with risk elements that may lead to adverse mental states, physiological states, and physical or mental limitations that may serve as precursors of unsafe acts. The responsibility of mitigating factors leading to adverse mental states, physiological states, and physical or mental limitations is placed on the operator to prevent unsafe acts. For instance, the risk management section of supplemental oxygen (high altitude operations) states the applicant demonstrates the ability to identify, assess and mitigate risks, encompassing the following:

- High altitude flight
- failure to use supplemental oxygen
- management of compressed gas containers
- Combustion hazards in an oxygen-rich environment.

Therefore, tasks relating to or involving hazardous altitudes, aeromedical and physiological issues, high-altitude flight, and supplemental oxygen management were classified under the condition of the operators. Table 3 shows the tasks grouped under the operator's condition.

Table 3

Condition of the Operators	
• Human Factors	• Pressurization
• Supplemental Oxygen	• Emergency Equipment & Survival Gear

7.1 Discussion

The research findings revealed that human factors training is critical in flight training to ascertain that pilots can perform duties efficiently with minimal human errors. Furthermore, the findings revealed that the risk management elements that are most frequent in Commercial Pilot-Airplane ACS are the ones involving situational factors. In relation to our findings, Endsley (1997) says, "Situation awareness is recognized as one of the most critical aspects in the aviation domain, and many features of our high technology environment can act to degrade situation awareness subtly; however, including high levels of complexity, out-of-the-loop performance decrements resulting from automation, and lack of synergy in human and machine decision making." In support of Endsley's premise, the risk element under navigation systems and radar service stated that the applicant for a commercial pilot license demonstrates the ability to identify, assess and mitigate risks, including failure to manage automated navigation and auto-flight systems. This is because improper automation management could lead to various accidents and incidents in the aviation industry (Gawron, 2019). For instance, American Airlines Flight 965 lost situational awareness and crashed due to improper automation management (Air Crash Investigation, 2015). "An Associated Press article by Randolph E. Schmid reported the probable cause as being (1) Failure of the flight crew to properly execute their approach; (2) The crew's lack of situational awareness, and (3) The crew's failure to revert to basic radio navigation when they became confused about their location" (Ladkin, 1999, p.9, para i). Furthermore, according to Gawron (2019) common errors identified with automation are incorrect settings, poor understanding of the system and genuine error, and poor monitoring and vigilance. These errors are stated under the risk elements in tasks classified under situational factors.

Our findings also revealed that personnel factors are the second predominant risk element in the commercial airplane ACS, and the dominant factor is communication. In the past decades, poor communication has been one of the factors affecting flight safety. In the commercial airplane ACS, communication cuts across many tasks and is identified as one of the risk elements that must be mastered to enhance safety. In addition, research revealed that communication issues had comprised a sizeable portion of NASA's aviation safety reporting system database since its inception. This shows that communication issues and other personnel factors should be taken seriously in flight training environments since they have been identified as risk elements capable of leading to unsafe acts.

Furthermore, our findings showed that emphasis must be placed on factors affecting pilots' performance in flight. Pilots are humans and can be subjected to psychological and physiological imbalances. Research revealed that mental or physiological stress and physical/mental limitations could prevent the operator from performing flight-related duties efficiently (Guastello, 2014).

One of the operations that can degrade mental performance is high-altitude operations without supplemental oxygen. High-altitude flight can subject pilots to hypoxia, a state of lack of sufficient oxygen in the blood, tissues, and/or cells to maintain normal physiological function (FAA). Due to this fact, pilots should be properly trained to ensure they understand that the onus is on them to be conversant with the risks associated with high-altitude operations and ways to mitigate the risks.

8.1 Recommendations

Enhancing human performance in flight operations begins with training to elucidate human capabilities, limitations, behaviors, and relationships with systems. Adequate training in aircraft systems and automation is extremely important to enhance human performance and reduce workload, stress, fatigue, and human errors. Flight lessons should be introduced in advanced aviation training devices (AATD) or basic aviation training devices (BATD) to ensure that pilots gain mastery over them and understand associated risk elements before they are conducted in the aircraft. AATD/BATD is cost-efficient and affords pilots enough time to practice and become proficient in managing risk elements associated with each task.

A Series of distractions can be introduced, especially during automation training to assist pilots in developing skills to effectively manage automation in a high workload environment, prioritize flight activities, and reestablish situational awareness. Research showed that automation directly impacts situational awareness by changing vigilance associated with aircraft flight path monitoring and pilots assuming passive roles instead of an active role in controlling the system (Endsley, 1996). These impacts can be minimized through effective training and provide the crew with the ability to maintain situational awareness. Distractions such as dealing with unexpected situations, unexpected traffic alerts, head-down work, communication interruptions, changes in planned approaches, and many other distractions can enable pilots to gain the skill to manage several tasks concurrently.

Scenario-based training (SBT) is an effective way to challenge pilots with various flight scenarios of risk management elements to improve decision-making and skills that can mitigate human errors (Summers, 2007). SBT should be incorporated into the training syllabus to provide a uniform training experience for company pilots and illustrate human factors problems in flight training. SBT engages pilots by stimulating their brain activity, encourages them to think critically, and helps them develop mental toughness to solve aeronautical decision-making problems, such as situational awareness and crew resources management.

A structured script of real-world experiences must be created to meet each training objective in the ACS. So, the training manager can develop realistic scenarios that other instructors can use for their flying.

In addition, incorporating team-building techniques into the training syllabus will have a long-lasting impact on mitigating human errors in a complex environment by enhancing effective workload management, active monitoring of the aircraft flight path, effective communication, effective crew coordination, and flight deck automation management. The main goal of team-building training is for the crew to develop the ability to work together and achieve desired goals. Team-building training involves having two pilots in the simulator or having the instructor play the role of a crewmember. Each crew member's role is to be defined according to standard operating procedures (SOP), and each one is expected to speak up when things are not executed as planned. During the training, different scenarios should be introduced for each pilot to act as pilot flying (PF) and pilot monitoring (PM). If the instructor is acting as a crew member, intentional errors should be committed to help the pilot in training develop the skill of managing threats and errors as a team.

Furthermore, emphasis should be placed on sharing mutual respect by trusting the expertise of one another and becoming interdependent. Each crew member should be encouraged to remain committed to their duties and be willing to help when their partner needs assistance. Active monitoring of other people's duties is an essential component of team building, and it can be done by having each crew member monitor their partner and give constructive feedback. Finally, team-building training should encourage open discussion to help flight crews cultivate the ability to share views and communicate effectively.

9.1 Conclusions

A summary of these classifications can be found in Table 4.

Table 4

Summary of the classification of Commercial Pilot Airplane ACS Tasks under the Precondition for unsafe acts of HFACS

Situational Factors	Personnel Factors	Condition of the Operators
40	6	4
80%	12%	8%

Based on the classification of risk management elements in the ACS using the preconditions for unsafe acts of HFACS, more risk elements are associated with tasks involving the physical environment, tools, or technology. This clearly shows that situational factors have the highest number of tasks involving human factors under the Precondition for unsafe acts of HFACS. Therefore, one of the ways to mitigate unsafe acts in the aviation industry is to ensure emphasis is placed on situational factors as defined by the HFACS because the inability to manage risks associated with situational factors could lead to a loss of situational awareness. In support of this, Endsley, Garland, & Georgia (2000) stated that "having a high level of situational awareness is perhaps the most critical factor for achieving successful performance in aviation" (p. 1).

Automation is one of the situational factors that is considered a double-edged sword. It increases productivity and reduces the operator's workload, thereby reducing errors (Kanki, Anca, & Chidester, 2019). However, a lack of system understanding and effective training has contributed immensely to automation mismanagement and error, which has led to many aircraft accidents (Ackerman, Talleur, Carbonari, Xargay, Seefeldt, Kirlik, Hoyakimyan, & Trujillo, 2017). Therefore, automation is identified in the ACS as a prominent risk element that needs to be addressed in the training environment to improve safety.

Personnel Factors such as communication, coordination and planning, and fitness for duty are the second most frequent risk management elements in the ACS that may be incorporated into the training program to mitigate human factors issues. Effective communication is vital to flight safety by aiding crew coordination and attention to managing all available resources in the flight deck. Personnel and situational factors can pose serious safety concerns and affect situational awareness.

Lastly, the condition of the operators is the third risk element that needs to be emphasized in the training programs to prevent unsafe acts. It is an important human factors problem in aviation that must be addressed to improve aviation safety. Research showed that conditions adversely affecting pilots' mental states can have detrimental effects on pilots' aeronautical decision-making and flight safety (Kanki, Anca, & Chidester 2019). In addition, the imbalanced psychological state of a pilot can affect the Storage and retrieval of information in the brain and set the stage for errors (Kanki, Anca, & Chidester 2019). Therefore, in flight training, emphasis should be placed on factors affecting pilots' cognitive performance to enhance flight safety.

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