IBN HALDUN UNIVERSITY
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF AIR TRANSPORT MANAGEMENT

**MASTER THESIS**

# ANALYSIS OF HUMAN FACTORS IN AIRCRAFT ACCIDENTS: THE CASE OF THE USA

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**THESIS SUPERVISOR**

**ASSIST. PROF. NİHAT GÜMÜŞ**

**ISTANBUL, 2021**

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# ANALYSIS OF HUMAN FACTORS IN AIRCRAFT ACCIDENTS: THE CASE OF THE USA

**by**
**NURCAN KIZILTEPE**

**A thesis submitted to the School of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Science in Air Transport Management**

**THESIS SUPERVISOR**
**ASSIST. PROF. NİHAT GÜMÜŞ**

**ISTANBUL, 2021**

# APPROVAL PAGE

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Air Transport Management.

Thesis Jury Members

| Title - Name Surname | Opinion | Signature |
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This is to confirm that this thesis complies with all the standards set by the School of Graduate Studies of Ibn Haldun University.

Date of Submission                                        Seal/Signature

ACADEMIC HONESTY ATTESTATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name Surname:

Signature:

DEDICATION

This thesis is dedicated to my better half Dr. Artür Yetvart Mumcu, my dear family and dear brothers Ergün Kızıltepe and Ali Kızıltepe and my sisterly friend Semra Camuka.

ÖZ

# UÇAK KAZALARINDA İNSAN FAKTÖRLERİNİN ANALİZİ: ABD ÖRNEĞİ

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Ticari havacılığın ortaya çıkışından bugüne sayısız uçak kazası yaşanmıştır. Her bir kazadan önemli dersler çıkarılmış ve havacılık sektörünün gelişiminde uçak kazaları sonucunda elde edilen veriler büyük rol oynamıştır. Bu gelişimi sağlayabilmek için uçak kazalarının ve kazaya sebep olan faktörlerin doğru bir şekilde analiz edilmesi hayati önem taşımaktadır. Sektörün gelişimi ile birlikte uçak kazası inceleme yöntemleri ve modelleri de gelişim göstermiş, zaman içeresinde birçok farklı model ortaya konulmuştur. Kazaların altında yatan sebeplerin analizinde kullanılan en güncel ve kapsamlı modellerin başında insan faktörlerinin analizinde ve sınıflandırılmasında kullanılan "Human Factors Analysing and Classification System" (HFACS) gelmektedir. Bu model kazaların sebepleri arasında yer alan gizli veya açık insan kaynaklı faktörleri incelemekte ve bunları sınıflandırmaktadır. Bu çalışmada nitel araştırma yöntemlerinden içerik analizi kullanılmıştır. National Transporation Safety Board (NTSB)'den veritabanından alınan, ABD'de, 2000-2018 yılları arasında gerçekleşmiş olan 245 ticari uçak kazası raporu incelenmiş ve bu kazaların sebepleri HFACS modeline göre sınıflandırılmıştır. Sınıflandırma için HFACS'in en güncel versiyonu olan HFACS 7.0 ve HFACS-ADF modelleri temel alınmış ve kazalar bu çerçevede kodlanmıştır. Araştırmanın sonucunda, ticari uçak kazalarının sebepleri ve bu sebeplerin birbiriyle olan ilişkisi ortaya konmaya çalışılmıştır.

Klasik HFACS uygulamalarının aksine, kazaların sebepleri sadece operasyonel ve örgüt seviyesinde incelenmemiş, aynı zamanda örgüt dışı sebepler de araştırmaya dâhil edilmiştir.

**Anahtar Kelimeler:** HFACS, İnsan faktörleri, Uçak kazaları

ABSTRACT

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Since the advent of commercial aviation, there have been numerous aircraft crashes. Lessons derived from each accident and the data obtained from these aircraft accidents have played a major role in the development of the aviation industry. To achieve this development, it is vital to analyse the factors underlying aircraft accidents properly. Different methods and models to analyse the factors that led to aircraft accidents have been introduced over time. One of the closest and most comprehensive models to today is the Human Factors Analysis and Classification System (HFACS). This model examines and classifies the latent or explicit human factors at all levels. Content analysis which is a qualitative research method was used in this study. 245 reports of commercial aircraft that took place between 2000 and 2018 in the USA are downloaded from the database of the National Transportation Safety Board (NTSB) and the causes of those accidents were analysed and classified according to the HFACS model. For classification, the most up-to-date versions of HFACS, HFACS 7.0, and HFACS-ADF models were taken as a basis and the accidents were coded within this framework. As a result of the research, causes of commercial aircraft accidents and their relationship with each other were tried to be revealed.

Unlike the classical HFACS applications, the causes of accidents were not only examined at the operational and organizational level, but also non- organizational factors were included in the research.

**Keywords:** Aircraft accidents HFACS, Human factors

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| ATC | Air Traffic Control |
| CRM | Crew Resource Management |
| DOD | Department of Defence |
| FAA | Federal Aviation Administration |
| GA | General Aviation |
| HFACS | Human Factors Analysing and Classification System |
| HFACS- ADF | Human Factors Analysing and Classification System- Australian Defence Force |
| ICAO | International Civil Aviation Organization |
| NTSB | National Transportation Safety Board |
| SCM | Swiss Cheese Model |

# CHAPTER I

# INTRODUCTION

Since the second half of the 1950s, the air transportation industry has paid enormous efforts to minimize the accident rate and these efforts have resulted in unparalleled levels of safety, to the point where flying in a commercial airliner is now safer than driving a car or even crossing a busy street in New York City. (Shappell & Wiegmann, 2001) Aircraft were inherently unforgiving and mechanically risky in the early days of aviation, and accidents were common. However, in the contemporary era of aviation, the literature suggested that human error was responsible for between 70% and 80% of aircraft accidents (Shappell & Wiegmann, 2001). The advancement of mechanical aircraft technology and rising aircraft reliability were directly tied to this discrepancy in the genesis of accidents. As a result, an increasing number of aviation firms have tasked their safety staff to design safety programs to address the decidedly complicated, and also frequently elusive, issue of human error in the last two decades (Wiegmann & Shappell, 2001).

Given the increased importance of human-related factors in aircraft accidents, different models and methods have been introduced to analyze and classify those factors. In this respect, the framework for the Human Factor Analysis and Classification System (HFACS) built an extensive, user-friendly instrument for diagnosing and classifying the human-related cause of aviation accidents (Wiegmann & Shappell, 2003). This instrument has been employed in the military and public sectors in the United States and Canada. In addition, its reliability has been demonstrated in several studies. (Shappell & Wiegmann, 2003; Wiegmann & Shappell, 2003; Scarborough, Bailey, & Pounds, 2005).

This study aims to apply HFACS to aviation accidents that occur due to human factors in the 21st century and to analyze the root cause of human factors in accidents. The analysis utilizes a data set covering 245 accidents that took place in the USA between 2000 and 2018. In addition to the traditional HFACS analysis, it also investigates the relationship between the root factors and creates a roadmap for the prevention of subsequent accidents (Dönmez, K., 2018).

The vast majority of applications of HFACS involves analyses of accidents in the 20th century. However, the fact that the total number of commercial air traffic doubled between 2000 and 2018 and that the share of mechanical errors in accidents decreased significantly with the use of more advanced the third and fourth generation aircraft, increased the importance of focusing on human factors in accidents taken place between these dates (Airbus, 2017). In this study, with the application of HFACS 7.0 and HFACS-ADF which are the latest versions of HFACS to aviation accidents in the 21st century, a more comprehensive approach has been displayed and not only organizational factors but also non- organizational factors such as airport personnel and regulatory issues which affect the accidents are analysed. In addition, the study was performed with a management perspective. Since there are no studies conducted with this point of view in the literature, the importance of this study is very great for the prevention of future accidents and incidents.

The next chapter of the study provides a literature review on human factors underlying aircraft accidents. The third chapter gives the data and methodology used in the study and the results of the analysis. Discussions, conclusion and recommendations based upon the study are presented in the last chapter.

# CHAPTER II

# LITERATURE REVIEW

The literature review chapter summarizes the existing theoretical and empirical work on the concept of human errors and their role in aircraft accidents. It also provides the basis for the analysis in the study by providing the structure and the levels of HFACS and their relationship in determining the causes of aviation accidents. In addition to the classical version, the latest versions of HFACS which are HFACS v.7.0 and HFACS-ADF are explained. Furthermore, previous research regarding the validity of HFACS is also examined that resulted in the determination of the research gap in the existing literature.

## 2.1. Human Errors

In general, giving a meaningful definition of human errors is quite difficult. They are frequently discovered after the occurrence: If a system performs less well than it should because of a human action or a disorder that could have been avoided with a reasonable human action, the reason will very certainly be characterized as a human error (Rasmussen, 1982). According to Shappell et al. (2007), human error is considered degrading or potentially lowering human judgment, the effectiveness, the protection, or the performance of the system. Similarly, according to Helmreich (2000), Sarter and Alexander (2000), and Shappell and Wiegmann (2001), the leading contributing cause of many major industry events, such as Bhopal and Chernobyl, is human error which is intrinsic in human failures. Human Error is sometimes cited in safety research. Most of these studies were based on studying human error theoretically and empirically; while others were perceptual, some took a holistic approach. For instance, Rasmussen (1982) carried out substantial human error analysis, which identified three types of human behaviour based on cognition, knowledge, rules, and skill conduct. Tasks based on knowledge include those used in making a strategy to tackle a new problem or situation. Although rule-based behaviour

is performed using several stored instructions or procedures, skill-based behaviour is spontaneously routine. Reason (1990) and Reason (1995) further expounded on Rasmussen's work by describing a human behaviour mistake as "unsafe deeds" performed in the front line before an operator's adverse event. Uncertain acts are carried out in various ways, including slips, deficiencies, accidents, and breaches. The first two are failures to execute where the action plan is adequate, but steps are not taken as intended. Both contribute to attention, recognition, memory, and selection failures. However, the authors note that errors take place when a plan is completed as planned yet insufficient to achieve its intended result (Reason, 1990; Reason, 1995).
Reason et al. (1998) noted that rules and regulations deviations are the ultimate type of dangerous, routine, or exceptional violations, increasing the likelihood of a mistake that leads to negative results. Although regular breaches are less severe breaches of regulations permitted by authority staff, and therefore customary, extraordinary breaches are severely different from rules and protocols which are not accepted by such staff. Recently, Li et al. (2018) classified human error as omission or commission which starts with a cognitive error that results is external error based on operators' task results. According to Shorrock and Kirwan (2002), if failure to do a required job at the expected time occurs when the operator does an operation inappropriately or at an unclear time, mistakes of commission occur. Besides, Shorrock and Kirwan (2002) stated that human errors had been divided into different ways to recognize acts that endanger employees' safety and the facility.

## 2.2. Human Factors and Accident Causation in Aviation

Several uses of diverse types of air vehicles contribute to the modern age of technology and operations which causes the mounting interest in aviation that stems directly from their demonstrated abilities in many fields. The changes in the modern age have led to significant human factors problems. Human factors play an important role in aviation, as they are crucial for saving lives and minimizing organizations' expenditure. With the aid of technical advances, aircraft reliability plays a vital role in controlling human factors in air accidents. Human factors are consistently seen as a fundamental cause of incidents in human aircraft, and according to Wiegmann and Shappell (2003), human error incidents range from 70% to 80%. In support of Shappell and Wiegmann (2000), over the last 40 years, there has been an increasing percentage of human error injuries than equipment failures. To effectively formulate countermeasures such as accident-prevention steps, Rash, LeDuc, and Manning (2006) argue that knowledge of human-related factors is required and that understanding can be achieved by introducing accident analysis techniques in existing bases of accident data. Several studies created models and frameworks for the accident because of the need to lower human error in air accidents, which resulted in deaths and cost considerable research, loss of aircraft property, and litigation resources. In support, Senders and Moray (1991) established that the aviation sector had witnessed the proliferation of mechanisms for human error in the 1970s. The overall rate of accidents in the last half-century caused this prolongation in the 1990s. Still, decreases in human error accidents did not lower rates of accidents associated with technical and environmental accidents (Wiegmann & Shappell, 2003). A study by Wiegmann et al. (2000) summarised over 100 research and technical papers that either directly present or use the errors framework to analyse data from human performance in a specific context or mission.

According to Shappell and Wiegmann (2009), HFACS studies incidents that are caused mainly by factors linked to errors and infringements based on skills. Lenné et al. (2008) note that the United States has shown that skill-related errors caused most injuries elsewhere. In support, Shappell et al. (2007) established that breaches were responsible for the fatal incidents when analysed in a fatality. Since then, several studies (Baysari et al., 2009; Celik & Cebi, 2009; Patterson & Shappell, 2010; Read et al., 2012) have compared the industry of aviation and other fields to classify the factors causing accidents. The results for accident causes in other sectors are consistent with those in the aviation industry. For example, maritime, railway, and mining studies showed that the leading causes of accidents are skill-based errors (Kim & Yoon, 2013). Although the human element is essential in its factors causing accidents, despite a distinction in each sector, the investigators have noted the addition of factors in the use of HFACS in other sectors. For instance, contributing factors from organization and supervisor categories arose when analysing incidents in different areas using HFACS. Patterson and Shappell (2010) found poor leadership to be the fundamental cause of mining accidents. On the same note, Baysari et al.'s (2009) and Kim and Yoon's (2013) studies in the railway sector found another category of outside factors, including regulators and industry decision-makers, and have incorporated management of resources and adverse types of mental stage into the preconditioning level. Competency and judgment mistakes in other fields such as the regulation of aviation and the entry of computer data were the categories established in both areas (Kotogiannis & Malakis, 2009; Bergeon & Hensley, 2009; Barchard & Pace, 2011). However, human mistakes are not altered events, and researchers may assign them several causes or variables. Researchers, therefore, showed the existence of associations between the causes when assessing incidents with taxonomic factors. For example, the aviation studies by Shappell et al. (2007) and Shappell and Wiegmann (2009) established a relationship with organizations, administrative and human crew abuse between the two cause group layers, judgment mistakes, and skill-based errors. Furthermore, researchers have also evaluated the relationships of the cause of error in the different levels of other domains.

## 2.3. The Human Factors Analysis and Classification System (HFACS)

According to Shappel and Wiegmann (2000), HFACS is a taxonomy of human errors that is designed to provide a systematic framework for defining and categorizing causal factors underlying incidents/accidents. The framework provided by the HFACS can be used to establish effective safety measures. On the same note, Harris, and Li (2011) state that HFACS is the most broadly used human factors study method at present. Wiegmann and Shappell (1997; 2000) have constructed this method based on Reason’s Swiss Cheese Model (SCM) (1990). The HFACS defines the problems and faults within the SCM, thus ensuring that the causes of incidents/accidents are categorized methodologically. It, therefore, acts as the instrument in real-world environments for accident investigators, researchers, and safety professionals (Wiegmann & Shappell, 2003). The HFACS system is a hierarchical framework and compiles nineteen human-related causes of accidents into four broad failure levels, similar to the barriers found in the SCM developed by Reason. The four levels involve both active and latent failures. In the first stage, functional failures, hazardous activities are present. Simultaneously, the other three levels included latent failures, preconditions for insecure actions, uncertain control, and organizational influences, and are dependent on the latter, as seen in Figure 2.1.

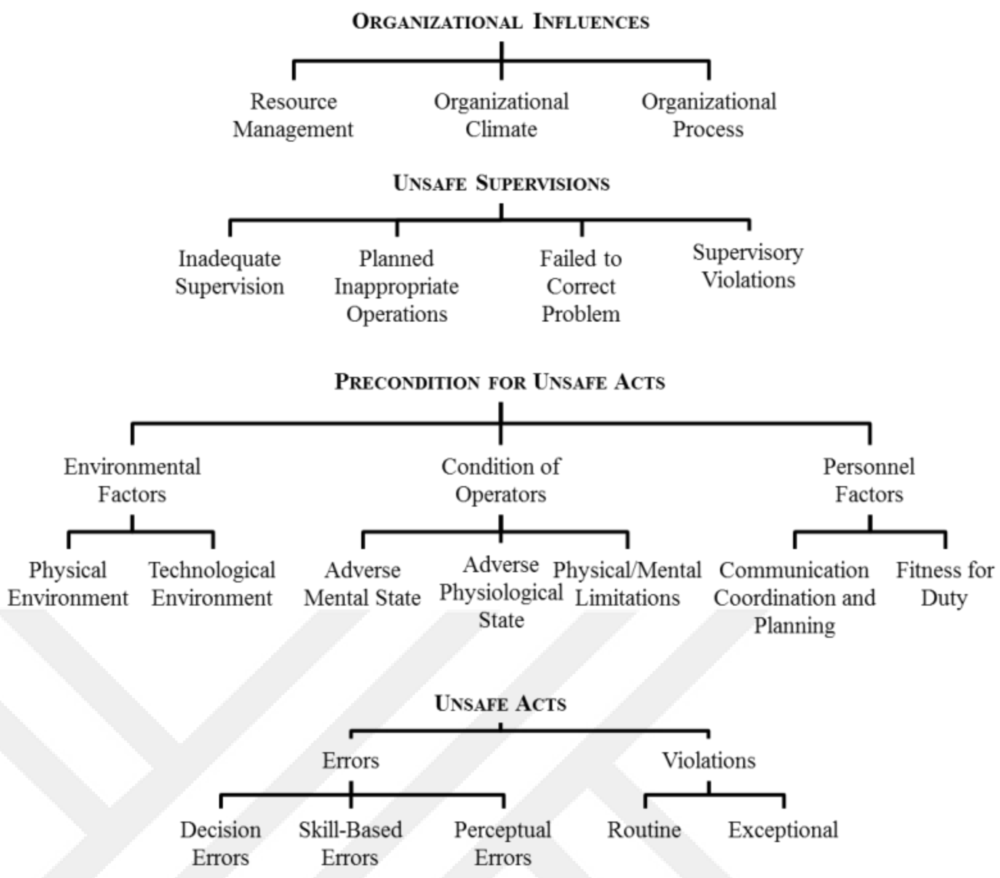



**Figure 2.1. Framework of HFACS (Shappell, 2009).**

## 2.4. Frameworks of HFACS

The frameworks of HFACS include four hierarchical levels and nineteen sub-levels that affect each other.

### 2.4.1. Unsafe Acts

The HFACS first level represents an operator's unsafe acts that led to the occurrence/accident. Unsafe acts centre on the people and place the blame on the operator for the accident. These unsafe actions are divided into two different groups: errors and violations.

#### 2.4.1.1. Errors

Errors are operators' acts, which fail to achieve the desired results and are applied to three specific forms of errors: competence dependent, choice, and perceptual. The wilful disregard of the operator's rules and regulations is classified into breaches, ordinary and exceptional. According to Patterson and Shappell (2010) and Shappell et al. (2007), the most common errors are skill-based mistakes. These physical errors occur in highly programmed tasks with little to no conscious thought. However, Airbus (2005) clarifies that the operator workarounds the normal activities during programmed control and forgets to check the structural repair. Generally, skill-based errors are often caused by memory and/or concentration deficiencies and frequently occur in the checklist as forgetful or incomplete steps or as a misplacement of steps.

The second form of error is those due to decisions that define an individual's intentional acting as intended, but the results suggest that the condition is insufficient or inappropriate. According to Wiegmann et al. (2005), there are three types of decision errors that include: knowledge-based, regulation-based and problematic resolution. Factors such as inexperience, time, and stress intensify the mistakes, which are known when the operator chooses an action plan which is shown to be the wrong protocol for the situation. In support, Rashid et al. (2010) state that errors based on the rule, also known as judgment errors due procedure, arise when the condition is not understood or the incorrect procedure is implemented. In many cases, the operator is faced with a problem that is not well known, or that does not require a creative solution for a formal procedure. The time to reach the best solution is seldom accessible in these circumstances. On the other hand, the third type of error due to perception occurs when the sensory information deteriorates, either visually, additively, or olfactory (Recanzone, 2003). The data itself is misinterpreted, but not because the input is used. Thus, the understanding of a person's condition and its reality differentiates.

#### 2.4.1.2. Violations

Violations are the acts of the operator and are thus considered deliberate without respecting existing rules and regulations. On the same note, Wiegmann et al. (2005) and Wiegmann and Shappell (2003) state that violations may be routine or exceptional etiologically. Violations due to routine are lesser in extreme and thus becoming customary, departing from regulations tolerated by authority staff. However, exceptional violations are different from routine violations since they are neither characteristic of the individual nor tolerated by authority and very difficult to predict. Although an example of a routine violation is where a pilot fails to use radar alerts of Air Traffic Control (ATC), non-obligatory co-pilot commercial aircraft operations are an exceptional example (Wiegmann & Shappell, 2004).

### 2.4.2. The Unsafe Acts Precondition

This level is the prerequisite for dangerous behaviour, including environmental, operator's circumstances, and personal factors.

#### 2.4.2.1. Environmental factors

There are two explanatory factors for the environment: the physical and the technical conditions. The physical environment defines both operating conditions (tools, equipment, etc.) and environmental conditions (temperature, atmosphere, etc.) (Wiegmann et al., 2005; Wiegmann & Shappell, 2003). The technical setting considers equipment and control design, the operators and equipment relationship, and displays the interface's characteristics, which is a crucial human error issue.

#### 2.4.2.2. Condition of Operator

The second compilation of Unsafe Acts Precondition is the operator's circumstances or conditions and is divided into three factors: psychiatric illness, detrimental physiological conditions, and physical/mental boundaries (Lenné et al., 2012). The operator's unpleasant mental disorder addresses symptoms such as mental exhaustion, distraction, carelessness, and complacence that can adversely affect an operator's efficiency. The operator's unfavourable physiological condition includes medical and physical disease, physiological failure, and physical weariness (Wiegmann et al., 2005; Wiegmann & Shappell, 2003). The category of physical and mental limitations applies to circumstances in which the operator's long-term capacity exceeds work demands, such as incompatible intellect and incompatible physical skills for safe work (Lee & Seppelt, 2006).

#### 2.4.2.3. Personnel Factors

In the last classification of insecure acting requirements, which is the portion of personal factors, two causal factors are classified: coordination of communications and preparation and fitness for work (Macrae, 2009). The organization of communication and preparation between staff, managers, departments, and teams includes examples of an individual failing to use all resources accessible. This precondition category for uncertain actions explains the actions the operator can do to construct the said preconditions. The group also consists of two HFACS variables. According to Shappel and Wiegmann (2000) and Wiegmann and Shappell (2003), the first one is CRM, the pillar of aviation history that makes it much easier to understand. This factor refers to poor coordination or cooperation between operating staff, including flight crews, air traffic controllers, and maintenance and support crews. The second aspect of HFACS in this category is the personal readiness to prepare the individual mentally and physically so that they do not perform properly at high levels. A classic example of such a factor is violations of crew rest criteria and auto-medication. According to Wiegmann and Shappell (2003), it should be explained that the violations mentioned above of the rules vary in time, space, and consequences from that which is dangerous. They affect the fitness of a person for the flight but cause no direct disorder.

### 2.4.3. Unsafe Supervision

According to Daramola (2014), this dimension is related to the decisions and performance of supervisors and managers that can influence frontline operators' performance. Unsafe supervision is divided into four categories: poor management, improper scheduled activities, failure to address a common problem, and the type of supervisory violations.

#### 2.4.3.1. Poor Management

Chauvin et al. (2013) assert that inadequate monitoring covers all situations in which supervision does or offers inadequate or insufficient direction, monitoring, and/or training. The intended inappropriate category of operations comprises situations where managers fail to assess the danger associated with a job, and therefore, put workers at unreasonable risk, including unsuitable personnel, a mission in non-reform, and an insufficient crew rest chance.

#### 2.4.3.2. Planned Inappropriate Operations

In cases where unacceptable circumstances, training, or behaviour in HFACS are detected, acts or conditions are non-corrected, where supervisory bodies agents fail to undertake corrective action or disclose such hazardous situations, this failing to correct a known problem is a matter of fact (Shappell & Wiegmann, 2000).

#### 2.4.3.3. Failing to Problem Correction

Applying rules and procedures by correcting of improper conduct or operations is under the supervisor’s duty. According to Shappell and Wiegmann (2000), this HFACS element is responsible for instances where supervisors know but are not corrected for specific actions or operations relating to safety areas. The failure to address a problem encourages a dangerous environment that directly affects the creation of unsafe actions.

#### 2.4.3.4. Supervision Violations

The category of supervision violations includes a deliberate disregard of existing rules and regulations by those in leadership positions. Wiegmann and Shappell (2003) stated that this HFACS element involves a non-compliance of the supervisor with the current rules. Examples of these supervisory breaches include allowing a pilot to fly the aircraft without sufficient qualification and lack of appropriate records. This type of infringement still paves the way for catastrophic disasters despite its rareness.

### 2.4.4. Organization's Influences

The fourth stage in the framework of HFACS includes the organization's influences, in which flaws and shortcomings can be tracked to their highest levels (Gonçalves et al., 2019). This group is divided into three main factors: control of resources and acquisitions, the organizational environment, and the organizational process (Shappell, 2009).

#### 2.4.4.1. Management of Resources

The management of resources/investments involves distributing top management decisions relating to resources, such as equipment, services, money, and human resources. According to Shappell and Wiegmann (2000) and Wiegmann and Shappell (2003), the HFACS component covers total organizational capital, including human resources, financial investments, facilities, and equipment. As Reason's (1990) model shows, any organization faces conflicting interests that oppose production goals with security objectives. For example, the absence of financing for the correct and secure equipment adversely affects an operator's efficiency and safety. All organizational decisions that affect operations and safety are responsible for this factor.

#### 2.4.4.2. Organizational climate

The organizational environment category is defined as the factors that include the policies, structure, and culture that influence employees' performance (Shappell, 2009). The organization group of processes is defined as a decision-making mechanism that regulates an organization's daily activities, including operations, procedures, and surveillance. Late circumstances are often ignored during accident investigations at the organization's level; however, according to Hobbs (2008), HFACS allows understanding of the said factors during the review and examination phase.

#### 2.4.4.3. Process of an Organization

The last HFACS factor of organizational influences defines the organizational policies and rules governing routine work within an organization, including the development and use of standard operating procedures and structured supervisory methods (Shappell, 2009). The operating speed and production quotas can be dangerous for protection; for example, in the management's working conditions, the management should also observe and monitor the resources and the atmosphere and perform the required supervisory function for ensuring that the work environment is secure and efficient (Shappell, 2009). If not, the protection could be breached again.

## 2.5. Classification of Human Factors Analysis and Classification System

Two updated versions of HFACS are HFACS v. 7.0 which is developed by DOD in the USA and HFACS- ADF which is developed by the Australian Defence Force.

### 2.5.1. HFACS v. 7.0

During the validation and ensuring the efficiency of the scores, the classification systems used for safety evaluations need to be regularly revised. 711th Human Performance Wing from the United States Air Force Research Laboratory developed and validated version 7.0 of the DoD HFACS (King et al., 2015). The HFACS update's primary objective was to improve reliability among raters and to retain compatibility with existing databases. According to King et al. (2015), the HFACS v. 7.0 had 149 codes before 2013, many of which have been seldom or have not been used. A gradual checklist was established, systematically directing researchers through “nanocodes,” thus simplifying and rewriting the HFACS rating code. Although the conclusion recognizes that the taxonomy of “optimally accurate” human factors still need to be achieved, constructing a guiding review list offers a reliable context for using a popular HFACS in various databases. The figure below shows an adapted flowchart of the HFACS v. 7.0.

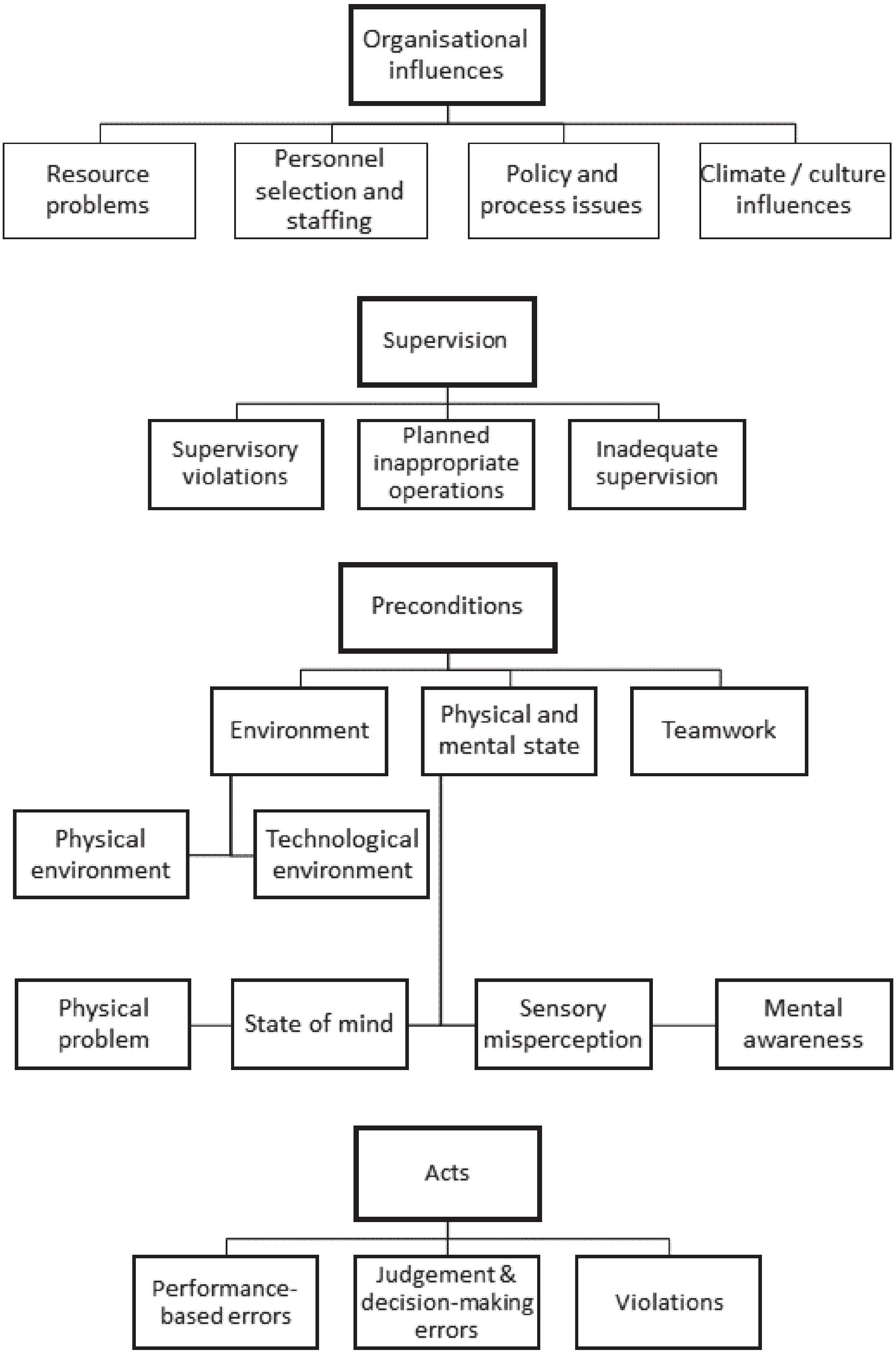



**Figure 2.2. HFACS v. 7.0. (King et al., 2015).**

The updates of HFACS index are shown in the table;

**Table 2.1. DOD HFACS 7.0 taxonomy**

| | | |
|---|---|---|
| **Acts** | Performance-Based Errors | When a particular action is carried out in such a way that it results in a mistake. |
| | Judgement & Decision-Making Errors | When managerial methods or policies have an impact on system safety, either directly or indirectly, resulting in inadequate error management or creating an unsafe condition. |
| | Violations | When someone deliberately disregards the rules and directions. Violations are done on purpose. |
| **Preconditions** | Physıcal Environment | Individuals' activities are influenced by weather, climate, fog, brownout (dust or sandstorm), or whiteout (snowstorm). |
| | Technological Environment (Workplace And Equipment) | When a person's activities are influenced by machinery or the design of their workplace. |
| | Physical Problem | Clinical or physiological disorders that could put you in danger |
| | State Of Mind | When a person's character traits, psychosocial issues, psychological disorders, or incorrect motivation combine to create a dangerous situation. |
| | Sensory Misperceptıon | When management fails to effectively prepare or assess the risks involved with an operation, unneeded risk is introduced. |
| | Mental Awareness | Factors affecting an individual's perception or behaviour due to a lack of attention management or consciousness. |
| | Teamwork | Individual, crew, and team interactions resulting in human mistake or an unsafe condition during the planning and conduct of a task/mission. |
| **Supervision** | Supervisory Violatıons | Supervisors who knowingly disobey orders or policies. |
| | Planned Inappropriate Operations | When management fails to effectively prepare or assess the risks involved with an operation, unneeded risk is introduced. |
| | Inadequate Supervision | When departmental or command-level supervision is found to be ineffective or inadequate in identifying hazards, recognizing and controlling risks, or providing direction, training, and monitoring. |
| **Organizational Influences** | Resource Problems | When resources have an impact on system security, leading either inadequate error management or a dangerous condition. |
| | Personnel Selection & Staffing | When personnel management methods or policies have an impact on system safety, either explicitly or implicitly, resulting in inadequate error management or creating an unsafe condition. |
| | Policy & Process Issues | When policies and practices have a detrimental impact on performance and create a risky situation. |
| | Clımate/Cultural Influences | Individual actions are influenced by the work place within the business, leading human error. |

Source: https://www.safety.af.mil/Divisions/Human-Factors-Division/HFACS/

The nanocodes used in coding process for each level is given in Appendix-IV.

### 2.5.2. The HFACS-ADF

This is a system of classification of incidents used extensively by the Australian Defence Force (ADF). Although the original HFACS is mainly intended for the flight crew's operations, HFACS-ADF is used to identify the causes in the entire Australian Defence Force Army, Naval, and Air Force such as maintenance issues and regulatory issues. HFACS-ADF taxonomy developed an additional level called «defences» (*see figure 3)* including ATC issues, maintenance issues, regulatory issues and airport personnel issues to categorize the non- operational factors. Falconer (2006) stated that HFACS-ADF had not been tested previously for reliability, but users have challenged its reliability in the past. Furthermore, Hsiao et al. (2013) and Walker (2007) noted that findings for HFACS (original) in non-flying areas had been little good, especially outside of the United States. In other sectors and nations, including in the ADF, Cohen et al. (2015) noted that there might be reasons such as the lack of comprehensive official training in HFACS. However, Cohen et al. (2015) acknowledged that the formal HFACS training results in a greater consensus than without training. Even in these courses, training was not adequate, with many studies reporting moderate reliability to deliver consistently reasonable reliability. Real-world users of accident and incident classification systems are generally moderately competent in the field, have minimal human factors training and classification systems for incidents, and use classification systems for several years. The challenge is to offer them a classification scheme, which will help the coders find a consensus despite the said limitations. Therefore, the HFACS-ADF is an excellent way to evaluate many different methods to improve safety for other hazardous industries in an ADF setting, with a view of accident and incident systems classification for reliability improvement.

## 2.6. HFACS Validation

Even though there are limits to research on assessing the classification of human errors schemes, HFACS is an exception. During its production, the efficacy of HFACS was investigated, and yet Beaubien and Baker (2002) denounced this research since it was carried out only by the founders. In addition to developers, however, several researchers started investigating its usefulness. For instance, Wiegmann and Shappell (2017) established that the use of human context error depends on the degree that a system is sound and consistent in the real world. On the contrary, McDermott (2011) points out that, in scientific study, both forms of validity, i.e., external validity and internal validity, are primarily significant. Besides, Wiegmann and Shappell (2001) stated that HFACS founders proposed that a human error framework, completeness, accessibility, diagnostic, and reliability evaluate four criteria at least. In the following sections, the four requirements, comprehensiveness, accessibility, diagnosis, and reliability, used for validating the HFACS system are addressed in depth.

### 2.6.1. Comprehensiveness

Comprehensiveness implies the system's capacity to describe and/or classify all important incident/accident information. Since there are no statistical instruments to quantifying this criterion, Wiegmann, and Shappell (2003) stated it could be considered thorough by mapping the human error structure in the current organization accident database while incorporating any event/accident cause. At first, according to Wiegmann and Shappell (2003), the credibility validating HFACS had a basis from its submission to United States military and civil aviation databases. The framework was then extended to other fields such as mining, building, railway, oil and gas, marine, and safety, among others. These experiments also show that the accident causal factors can be categorized using separate causal categories from the HFACS. Such a study offers insight into potential accident prevention strategies.

### 2.6.2. Usability

Usability is the capacity of the system to be used in industry for practical purposes. The usability of HFACS was suggested, like comprehensiveness, as an investigation and research method for accident causation, by organizations such as the United States Navy/Marine and United States Army (Shappell & Wiegmann, 2001). Such active implementations have subsequently been observed in various industry sectors, including traffic control in the air (Broach & Dollar,2001, 2002), civil aviation (Wiegmann et al., 2005; Shappell et al., 2007; Inglis & McRandle, 2007; Shappell et al., 2007; Li et al., 2008; Lenné et al., 2008; Ting & Dai, 2011), and maintenance of aviation (Rashid et al., 2010).

### 2.6.3. Diagnosticity

Shappell and Wiegmann (2001) defined diagnosticity as the system's capacity to display links between errors and their causes and trends. HFACS framework has been checked initially on a case-by-case basis using aviation data sets. Dekker (2001) questioned how closely connected human error to the operating environment was to the HFACS taxonomy. Nevertheless, studies by Li and Harris (2006), Li et al. (2008), Tvaryanas and Thompson (2008), and Berry et al. (2010) examined statistical links between HFACS levels and causal categories. These analyses statistically characterize the propagation of behaviors and decisions in higher management levels around the enterprise, resulting in dynamic errors and incidents.

### 2.6.4. Reliability

It is also critical that the HFACS follows a certain reliability level and the previous requirements, honesty, usability, and diagnostics. Reliability usually refers to the degree to which a frame, testing, or measuring tool produces the same result in repeated tests (Solway et al., 2001). Reliability assessment is primarily a priority for several sectors, including behaviour, psychology, medical, and social science, especially in developing new approaches, tests, devices, and instruments. Shappell and Wiegmann (2001) used a military air accident database, particularly the Marine Corps, for the inter-relator reliability evaluation of the HFACS, which is based on its development process regulated by the accidents in terrain. Three raters classified multiple causal factors in these experiments, with the reliability calculated for each rater pair using Cohen's Kappa. The range of Cohen's Kappa was between 0.65 and 0.70 during the previous research. In the study by Shappell and Wiegmann (2001), Cohen's Kappa increased from 0.93 to 0.95 in the latter research, possibly because the continuously improved definition of HFACS causal categories indicated that the reliable framework was established for this area to be utilized. The HFACS inter-rater reliability was subsequently expanded by Weigmann (2000) to include two different data sets on commercial air traffic incidents. Expanding this report's sample size, Weigmann and Shappell (2001c) performed an investigation using a data set of 2,500 general aviation incidents involving over 6,000 causal factors listed in five raters, which has the most considerable inter-rater reliability evaluation of HFACS to date. The average Cohen's Kappa value was 0.72, which means that the system was significantly accurate (Sun, 2011).

Li and Harris (2005) also investigated the issue, similarly to the developers of HFACS, the interrater reliability of 523 air force incidents involving over 1,762 causal factors in the ROC Air Force aircraft. A pilot instructor and aircraft psychologist separately classified such variables, and Cohen's Kappa and percent agreement tested their reliability. The results from Cohen's Kappa showed good reliability between the two variables without informal agreement. More recently, the Australian military air traffic control (ATC) environment assessed the reliability of HFACS in inter-raters (Olsen, 2011). Two coder classes, three ATC experts on human factors, and four air traffic controllers trained individually in self-training workbooks of 14 elements, pre-identified by HFACS researchers. The results showed insignificant reliability in the study variables.

## 2.7. Application of HFACS in Aviation Accidents

O'Connor (2008) examined the DoD-HFACS system inter-rater reliability by establishing the inter-group inter-rater reliability coefficient and 123 coders' percentage. These coders have defined and listed the human factors that have caused two aviation malaise situations: students of the United States Navy and Marine Corps School for Aviation Safety. While the percentage agreement ranged from 53% to 99% at a categorical level, which fluctuated between fair and excellent inter-rater reliability, the percentage agreement at the Nano level ranged from 24% to 43%, suggesting that reasonable and satisfactory levels of inter-rater reliability were not met. However, in the latest O'Connor and Long (2011) study, the cause of an aviation incident was via an interview with a United States Navy officer. The analysis indicates a categorical average Fleiss' kappa of 0.76, which is a modest degree of inter-rater reliability.

Olsen and Shorrock (2010) examined the compatibility between the HAFCS Australian Defence Force's inter-rater and intra-raters (HFACS-ADF) frameworks in a percent agreement calculation. The percentage agreement was 39.9 percent at category level, and 19.8 percent at nano, respectively, and both found the inter-rater reliability to be inappropriate. Four ATC members classified five accounts of accidents during a 4- to-20-month span to examine the reliability of the intra-raters. The findings showed the percentage agreement between 36.2% and 46.2% and between 26.7% and 43.8% at nano at the category level. The reliability between and inside raters was also very poor, and the HFACS-ADF was not consistent. A related analysis by Tvaryanas and Thompson (2008) used the HFACS system to identify recurrent error mechanisms in 95 airplanes of remoted pilots and security accidents given to the United States Air Force Safety Center from 1997–2005. Besides, 95 aircraft were analysed in the United States. The use of a tree scheme that evaluated the active and latent faults relationships, including the detection of error routes quantitatively, is an essential feature of this research. Four repeated error paths have been found concerning four kinds of active HFACS failures. Two related to environmental awareness mistakes, 57 percent included those of crew members. The results further showed related to environmental perception. On the same note, Berry et al. (2010) designed research outside the aviation field, while most research that examined the active and latent errors correlations with HFACS system basis were aeronautic. In seven sectors, from maintenance to mining to entertainment, the emphasis was to identify active errors and latent conditions relationships in researching common human error pathways. Comparing the adjacent and the non-adjacent levels resulted in important causal factor pairings using Pearson's Chi-square test, the odds, and the relative risk ratio. There have been 15 crucial causal category pairs, twelve on the adjoining tier analysis and three on the non-adjacent tier analyses.

Tvaryanas et al. (2006) studied 221 remotely controlled aircraft inactivities within the United States armed services over ten years in a report entitled “Human Factors in Remotely Aircraft Operations.” They tried to examine operator errors’ distribution and determinants while analyzing the human factor using the DoD- HFACS. The findings showed that 60.2% of the malfunctions involved operational human casually-related causes. The suggestion being made is that latent failures are the most frequent and were correlated with operator error and mechanical failures. Another study by Tvaryanas and Thompson (2008) described recurring HFACS pathways in the United States accident database. They used exploratory analysis of the main component to evaluate the structure of remotely piloted aircraft within the collection of crew member mishaps. From October 1996 to September 2005, 95 malfunction incidents were examined, while 433 human-causal factors were identified. The malfunction data set was reduced to 8 factors using exploratory factor analysis and still makes up 72% of the initial dataset variance. The authors found, "perception and skill-based error pathways shared similar latent failures and together accounted for most related mishaps by the crewmembers. The study found HFACS categories of resource/acquisition management, business processes, and technical environments to be commonly latent failures" (Tvaryanas & Thompson, 2008, pp. 528-529). This study shows an example of a systemic approach for understanding a misunderstanding database by presenting the active and latent failures links and related probabilities. The study indicates that the descriptive method of a more structural approach fosters the mathematics of human performance defects with systemic factors.

Late deficiencies involving operational variables and technical environments have caused most injuries. The findings of 2 separate approaches were analysed by O'Connor et al. (2010), and human safety issues were identified in the United States Naval Aviation. First of all, 47 F/A-18 and 16 H-60 misalignments were analysed with the DOD HFACS taxonomy. The second approach was to examine the answers of 68 squadrons to a survey on problems of the human element perceived as the critical issue. The study assessed various questions about the squadrons and the effects of the DOD HFACS review. Nano comes from DOD HFACS were not seen among squadrons as significant concerns. In this report, HFACS was recommended in terms of results and interpretation.

On the other hand, Scarborough et al. (2005) investigated Air Traffic Control (ATC) operational errors employing the operational error reasons using the HFACS system. They compared HFACS and other available methods and chose to use HFACS on 10,754 operational error reports from 1998 to 2002. Two ATC experts trained the HFACS system with over 15 years of experience, and their classification was done separately from the other coding device. For their grouping, the Kappa coefficient determined suggested a high degree of agreement. As such, HFACS was a valuable taxonomy to identify causal factors in an ATC context associated with operational defects.

The United States Department of Defence (DoD), as a recommended model for "a framework that organizes the human factors found by the investigation", adopted version 7.0 of the Human Factors analysis and classification system (HFACS), which offers a standard reporting classification system (DoD, 2014)."The DoD-HFACS model offers a multidimensional and systematic approach to error and failure prevention" (DoD, 2014). For this analysis, the HFACS taxonomy was adopted. As the basis for the analysis were the NTSB multi-engine accident studies, available between 2006 and 2015, Title 14 CFR, Part 91 General aviation (GA), and Part 121 air carrier (AC). The researchers and other industry experts assessed any likely cause noted in each accident report and classified it centered on the DoD-HFACS version 7.0 categorization (DoD, 2014). Depending on its expertise in causal analysis, these industry experts were chosen. Following this work's purpose, the option of causal analysis expertise is sufficient to study 70 symptomatic and latent causal relations. These researchers have coded the data and compared them. In cases where the assessors did not agree, further review and community analysis of disparate likely triggers with the comprehensive report details helped overcome the conflicts during the final categorization. At the second level of definition, the HFACS Version 7.0 taxonomy was added. This has been achieved so that the granularity of the data produced can be limited at a level that provides valid claims than prior studies using earlier HFACS models. Besides, HFACS Taxonomy's secondary level can easily be extended to several systems, while the tertiary level is an aviation domain. The tertiary level offers secondary level definitions to promote the creation and validation of data. In another study, O'Connor (2008) tested the DoD-HFACS version 7.0 reliability. The author concluded that United States Navy and naval aircraft receiving malicious investigator training could not achieve acceptable reliability (O'Connor, 2008). While raters could agree on unused nanocodes, they could not achieve consistency in their use of nanocodes ("only seven nanocodes were available for 50% or more of the participants who agreed on the selection of a nanocode," p.602). O'Connor (2008) noticed that the number (147) of available nanocodes puzzled raters and that the overlap concepts were presented in the nanocode. Besides, the author stated that the numbers (147) of usable nanocodes and the conflicting definitions of the nanocode had puzzled raters (O'Connor, 2008). Collapse codes increased the reliability between the raters (O'Connor, 2008). Therefore, O'Connor (2008) recommended the expansion, parsimony, and mutual exclusion of nanocodes. O'Connor (2008) asked subject experts to study the nanocode to decide if they could be omitted or combined. O’Connor (2008) suggested that nanocode’s standard could be dropped if there was no reasonable reliability without intensive training.

Similarly, in 2011, four expert raters, Code 54 United States Air Force Academy (USAF), class A, were prepared by Human Factors Professionals of the Three Service Safety Centres, for presentation by Aerospace Medical Association, Human Factors Research & Classification System version 7.0 (O’Connor & Walker, 2011). The authors found that the Kappa coefficient .5494 was greater or equal to 76 out of 147 (52%) nanocode (O’Connor & Walker, 2011). The authors suggested that the code definition be improved and an organized curriculum is created (O’Connor & Walker, 2011). The DoD-HFACS version 7.0 was used in the following experiments, and fewer nanocodes were found (102, rather than 147). Kappa’s average coefficient has grown to 0.84 with expert coders, while new coders have continued to fight to achieve .2453 and .3239 as Kappa coefficients. O'Connor and Walker (2011) argued that a decision-taking algorithm is created, that DoD-HFACS should be redesigned in larger buckets (even if granularity is sacrificed), and that expert coding at the nanocode level is restricted.

Similarly, Wiegmann et al. (2005) applied the HFACS system to define the precise nature and support in generating intervention programs for human errors in general aviation. They used the FAA and other safety agencies' ten unanswered questions about the fundamental essence of human error in general aviation to guide their research. Data were gathered from the 1990-2000 NTSB database on general aviation incidents. As subject experts from the region of Oklahoma City, United States, seven general aviation pilots were recruited. The pilots were exposed to 16 hours of lecturing and practices on the HFACS System. Two random pilots were allocated to each accident, and inconsistencies were reconciled in classification. The researchers were able to analyse the findings and respond to all the questions. They identified many ways in which the death rate in general aviation accidents can be reduced.

Furthermore, in an analysis of 239 General Aviation (GA) accidents reported in Germany in 2004, Dambier and Hinkelbein (2006) applied the HFACS system. An accident had to involve a German pilot in the study, irrespective of where the incident took place. The methodology used in the study was not fully published, but the findings showed several parallels to previous HFACS investigations, primarily in the United States. The researchers found HFACS to be an essential method for analysing aviation accidents. Their results concurred with those by Detwiler et al. (2006), who investigated general accidents that were more than 17, 000 and compared them to the remainder of the United States to detect the human errors types. Data from the NTSB and FAA databases were collected on available aviation accident data from 1990 to 2002. Six pilots of general aviation, with over 1000 hours of flight, as subject-matter experts, were engaged from the area of Oklahoma City in the United States. They had been trained for 16 hours, including lectures and practice on the HFACS system. Two random pilots were allocated to each accident, and the classification inconsistencies were reconciled. There was no quality assurance or reliability protocol. The findings indicate that Alaska's human error forms did not vary significantly from the rest of the United States. Still, a different method must be used to achieve the optimal FAA general aviation safety standard in Alaska.

Most studies aimed to obtain knowledge of the accident causes by reviewing history or second-hand data in organizations. While many studies evaluate services' accidents within the United States Defence Department, several studies that analyse general aviation accidents in various countries are also available. In an HFACS analysis applied to "Civil Aircraft Accidents in India," 48 accident reports between 1990 and 1999 were analysed (Gaur, 2005). The classification was based on the author's reports and the independent assessor, while the goal was to identify causal factors (Gaur, 2005). The study showed that 37 out of 48 incidents involved one or more human factors. Li and Harris (2005) reviewed 523 air force aircraft accident reports between 1978 and 2002 in the China Republic as another example of the HFACS analysis. The authors were concerned with quantifying the relation between the HFACS taxonomic levels and components (Li & Harris, 2005). The study identified the joint paths of four levels in the HFACS between categories and indicated that latent conditions in the organization facilitate active failures. The analysis aimed to evaluate the route in HFACS instead of assessing the structure during the accidents. Between 1978 and 2002, Li and Harris (2006) examined 523 air force accidents in China while adopting the HFACS system. The analysis used the lambda (ć) of Goodman and Kruskal to assess the lower and the higher categories relationships. During this analysis, the four levels of HFACS taxonomy were linked to different error pathways. For example, weak organizational decisions have a considerable impact on supervisory efficiency, thereby affecting requirements for insecure actions and indirectly affecting pilots' operational performance.

Similarly, between 1999 and 2006 in the China Republic, Li et al. (2008) analysed the HFACS system to evaluate 41 civil aviation accidents. The study described pathways related to operational failures in the above three stages, preconditions for uncertain actions, and unsafe supervision.  Level 3 and the category of crew-resource management were linked to the immediate causes of numerous operational errors preceding accidents among several other categories in the second level. The findings support Reason's model (1990), which indicates that latent organizational conditions cause active failures. Hence, the researchers concluded that the study of the accidents in different areas of Aviation using the HFACS system offered interesting insights into the circumstances underlying human error. Besides, not only were unsafe human actions known, but the latent threats that led to these unsafe actions were also better understood from the studies outlined. Consequently, HFACS has also generated significant results to inform potential strategies for security mitigation in different fields.

## 2.8. Research Gap

Aviation, in particular, HFACS, is used for the analysis of accidents. Research from various authors has shown that HFACS is a standard theoretical method used for evaluating the human factors impact on aviation accidents based on the human error model of HFACS. Many studies use the HFACS taxonomy to exploit human impact in aviation accidents. However, almost no studies analyse the causes of aviation accidents using HFACS 7.0 and HFACS-ADF. Therefore, there is a need to evaluate this research gap and use HFACS 7.0 and HFACS-ADF frameworks.  The available study was conducted a decade ago, where the structural relationships of accidents between HFACS-ADF levels were studied. Due to the lack of current literature on the assessment of human errors in aviation using HFACS, there is a need to address this gap since accidents in aviation have changed over time.

# CHAPTER III

# DATA METHODOLOGY AND RESULTS OF THE ANALYSIS

## 3.1. Data and Methodology

Content analysis, one of the qualitative research methods, was used in this study. Coding was carried out by the researcher. The universe of the research consists of civil aviation accident reports. The sample of the research is the commercial aircraft accident reports published by the US civil aviation institution between 2000 and 2018. Within the sample, 225 aircraft accident reports were identified and all of them were coded using the data provided in the findings section of the reports. These reports were downloaded from National Transportation Safety Board (NTSB) official website (https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx). The reports are downloaded using the aviation database on NTSB website according to the criteria below:

- Accident information
  Event start date: 01.01.2000/ Event end date: 31.12.2018
  Investigation type: Accidents
  Injury severity: Fatal and Non- fatal
- Aircraft
  Category: Airplane
- Operation
  Operation: Part-121 Air Carrier/ Schedule: Scheduled
- NTSB Status
  Report status: Probable cause

The reason for choosing the time period between 2000 and 2018 is to understand why accidents still occur despite the fact that aircraft are equipped with the latest technology. Another reason is that the number of commercial flight traffic has doubled worldwide since 2000. Therefore, this time period, in which the traffic density doubles in a short period of time such as 15-16 years, is a period that should be emphasized in terms of safety. In order to better analyse organizational factors in aviation accidents, scheduled flights and flight operations of large airline companies were selected. The type of the reports published by NTSB were chosen as Probable Cause from the database to be used in the research. This type of report consists of the final report and a summary of the causes that led up to the event. Finalized and most accurate information about the event can be obtained from these reports.

The accident reports from the NTSB database were coded using HFACS v.7.0 and HFACS- ADF. In coding, only the cause factors defined by the NTSB were coded. The coder did not include their comments in the coding process. The coding was carried out as yes or no (1-0) for each class (Dönmez, 2018). The coding booklet published by the US Department of Defence was used.

The demographic variables in the accident reports are;
*Accident Type:* it shows the severity of the injuries in the accident that is categorized as "Non-fatal" and "Fatal",
*Model:* it shows the manufacturer of the aircraft involved in the accident
*Year:* it shows the years that the accident occurred.
*Flight Phase:* it shows the phases of the flights which the accident took place
*Event:* it shows the occurrences that happened during the accident.
*Operator:* it shows the airline company which operates the aircraft involved in the accident.

The human factors index (HFACS) developed in the USA was used in the coding. The original of this index consists of 4 themes as Acts, Preconditions, Supervision, and Organizational influence. Since the original HFACS index does not cover all the issues stated in the findings of the reports, the index was extended with 4 themes found in HFACS-ADF which are maintenance issues, regulatory issues ATC issues and Airport personnel, and non-organizational factors which were found to be lacking in the index were also included as Other Pilot Involvement, FAA Issues, Manufacturer and Airport Facility.

In order to better understand the HFACS coding process, case studies and the coding done are shown in Table 3.1. ;

**Table 3.1. Sample Coding-1**

| Occurrence | Unsafe Act | NTSB Code | HFACS Code | HFACS Nanocode |
|---|---|---|---|---|
| Tail strike | The Captain fails to follow the procedures | Procedures/Directives- not followed- pilot in command | Acts-Performance-based Error | AE103 Procedure not followed correctly |
| Overrun | The first officer fails to intervene before the accident occurs | Crew/Group coordination- not performed- Flight Crew | Preconditions-Teamwork | PP108 Failed to effectively communicate |
| Loss of control | Inspector / supervisor fails to detect incorrect rigging of elevator control system | Inadequate surveillance of operation-Company/operator management | Supervision-Inadequate supervision | SI001 supervisory/command oversight inadequate |
| Ground collision | Company procedures for turning an airplane into its parking position does not exist | Organizational issues-Management-policy/procedure-availability of policy | Organizational Influences-Policy/process issues | OP003 Provided inadequate procedural guidance or publications |

Source: NTSB (2020, December 15) Aviation Accident Database & Synopses, https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx

In the table, examples of coding for four themes of HFACS are presented. The coding made by the experts in the NTSB database was transferred to the HFACS database. As it can be seen from the table above, the expressions in the NTSB database and the expressions entered in the HFACS database are very close. The main purpose of HFACS coding is to reclassify all factors in accidents and incidents in a healthier framework by entering them into the database one by one. Therefore, the HFACS coding can be called “reclassification”. Furthermore, due to the structure of the HFACS framework, correlation analysis to these data is an important advantage of HFACS analysis (Dönmez, 2018).

**Table 3.2. Sample Coding-2**

| Occurrence | Unsafe Act | NTSB code | HFACS-ADF/ Non-organizational Factor |
|---|---|---|---|
| Loss of engine power | Manufacturer does not fulfil dimensional inspection and repair requirements for the gear box forward and aft diagram | Insufficient standards/requirements - Manufacturer | Non-Organizational - Manufacturer |
| Component/system failure/malfunction | Maintenance crew executes insufficient lubrication of jackscrew assembly | Lubrication-Inadequate-Maintenance personnel | HFACS-ADF-Maintenance Personnel |
| Miscellaneous/other | FAA fails to require that all runway crossing be authorized only by a specific air traffic control clearances | Procedure inadequate-FAA (other organization) | Non- Organizational-FAA issues |
| Overrun | The controller positions the airplane leaving the flight crew no safe option other than go-around | Improper decision-ATC personnel | HFACS-ADF- ATC issues |

Source: NTSB (2020, December 15) Aviation Accident Database & Synopses, https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx

The NTSB codes for accident findings include not only organizational factors but also the other factors that contribute to the accident as in the examples in the table above. According to the accident reports examined, these factors have minor effects and major effects. For example, maintenance personnel’s inadequate lubrication of the jackscrew assembly causes damage to aircraft. In the other example, the accident caused two serious and forty-two minor injuries which ATC personnel’s improper decision contributed to the accident. There are also fatal accidents which include non-organizational factors as contributing factors to the accident. In the last example seen in the table, the accident in which FAA failed to require the proper procedure claimed forty-four people’s lives (NTSB, 2020, April).

Original HFACS and HFACS v. 7.0 index do not cover non- organizational factors, HFACS-ADF extension and an additional non-organizational theme were used to classify those factors.

The hypotheses developed to reveal human errors by examining aircraft accident reports using the HFACS model described above are as follows:

**H1:** There is a relationship between demographic factors and human factors in aircraft accidents.

**H2:** There is a relationship between organizational factors and human factors in aircraft accidents.

## 3.2. Results

Official reports of 245 aircraft accidents between 2000 and 2018 were accessed from the NTSB database. All reports were individually analysed and the findings obtained as a result of the analysis are presented below. The abbreviations and numbers for each variable used in the coding process are given in appendix-III.

### 3.2.1. Descriptive Analysis-Frequency

Descriptive analysis of the study and frequency tables are shown below.

**Table 3.3. Data statistics of accident-related features**

| | | Accident Type | Operator | Model | Year | Flight Phase | Event |
|---|---|---|---|---|---|---|---|
| | Valid | 225 | 225 | 223 | 225 | 221 | 225 |
| | Missing | 0 | 0 | 2 | 0 | 4 | 0 |
| Std. Deviation | | ,186 | 16,566 | 3,366 | 5,168 | 3,873 | 5,801 |

As seen in the table above, a total of 225 samples were analysed. As a result of these analyses, the feature with the highest average value was seen as the operator, and the feature with the lowest was seen as the accident type. The feature with the highest standard deviation value is the operator, and the lowest one is the accident type.

**Table 3.4. Human Factors Theme Statistics**

| | | Frequency | Rate | Chi-Square*** | Total Rate | Total Frequency |
|---|---|---|---|---|---|---|
| Acts | Performance-Based Error | 58 | 13% | 52,80 | 27% | 119 |
| | Judgement& Decision-making Error | 59 | 13% | 50,88 | | |
| | Violations | 2 | 0% | 217,07 | | |
| Preconditions | Physical Environment | 46 | 10% | 78,62 | 28% | 124 |
| | Workspace | 4 | 1% | 209,28 | | |
| | Equipment | 39 | 9% | 96,04 | | |
| | Physical Problem | 3 | 1% | 213,16 | | |
| | State of Mind | 0 | 0% | - | | |
| | Sensory Misperception | 9 | 2% | 190,44 | | |
| | Mental Awareness | 8 | 2% | 194,14 | | |
| | Training | 4 | 1% | 209,28 | | |
| | Teamwork | 11 | 2% | 183,15 | | |
| Supervision | Inadequate Supervision | 5 | 1% | 205,44 | 2% | 10 |
| | Planned Inappropriate Operations | 4 | 1% | 209,28 | | |
| | Supervisory Violations | 1 | 0% | 221,02 | | |
| Organizational Influences | Resource Problems | 0 | 0% | - | 4% | 19 |
| | Personnel Selection& Staffing | 0 | 0% | - | | |
| | Policy& Process Issues | 18 | 4% | 158,76 | | |
| | Climate& Cultural Influences | 1 | 0% | 221,02 | | |

**Table 3.4. (cont.)**

| | | | | | | |
|---|---|---|---|---|---|---|
| **HFACS-ADF Defences** | **Maintenance Issues** | 22 | 5% | 145,60 | 24% | 108 |
| | **Airport Personnel** | 80 | 18% | 18,78 | | |
| | **ATC Issues** | 6 | 1% | 201,64 | | |
| | **Regulatory Issues** | 0 | 0% | - | | |
| **Non-Organizational** | **Other Pilot Involvement** | 24 | 5% | 139,24 | 14% | 62 |
| | **FAA Issues** | 7 | 2% | 197,87 | | |
| | **Manufacturer** | 10 | 2% | 186,78 | | |
| | **Airport facility** | 21 | 5% | 148,84 | | |
| | **Total** | 442 | | | | |

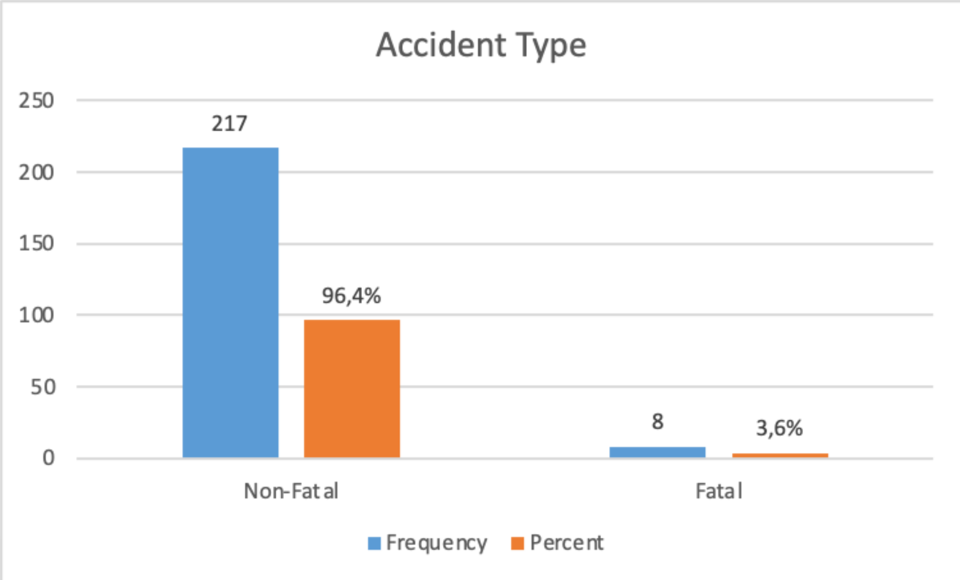
As can be seen in the table above, a total of 442 coding was done. This coding was carried out on 27 items in total under 6 themes as Acts, Preconditions, Supervision, Organizational Influences, HFACS-ADF extension and Non-organizational Factors. As can be seen in the table obtained as a result of the coding, acts coded under 3 items is 27% (Frequency=119), preconditions coded under 7 items is 28% (Frequency=124), supervision coded under 3 items is %2 (Frequency=10), organizational influences coded under 4 items is 4% (Frequency=19), HFACS-ADF extension under 4 items is 24% (Frequency=108) and non-organizational factors coded under 4 items is 14% (Frequency=62).

The chi-square values of the items with no coding were also not found. These items were excluded from subsequent analyses.

### 3.2.2. Frequency Tables

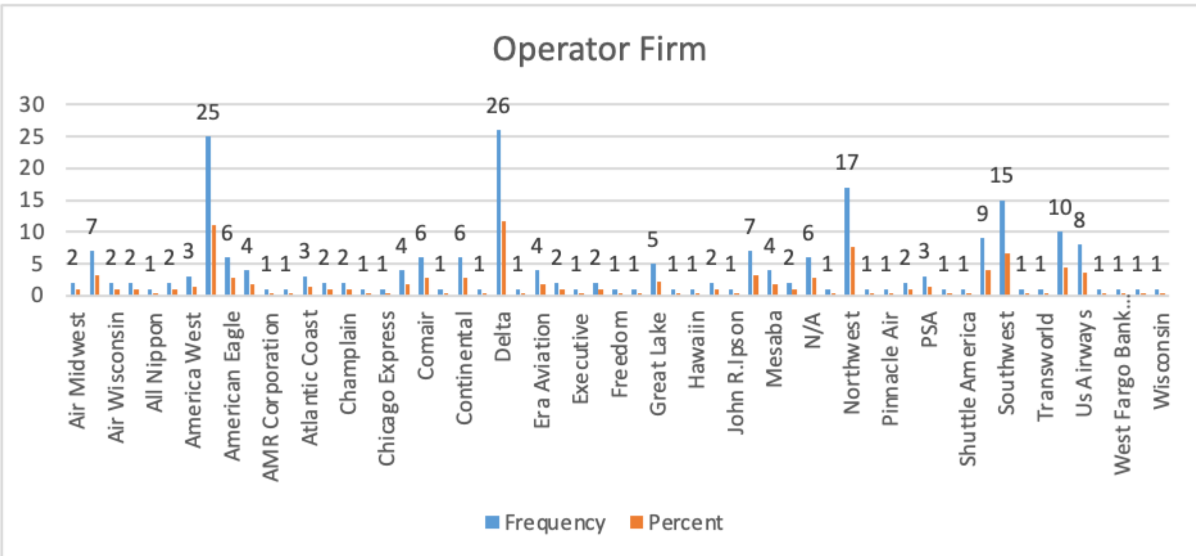
Frequency tables related to the features identified in the accident reports were analysed and the tables obtained are presented below.

**Graphic 3.1. Accident Type**




Among the examined accident reports, the number of non-fatal accidents is seen as 217, and 8 accidents are fatal in the accident reports. Non-fatal accident reports are 96.4% of total.

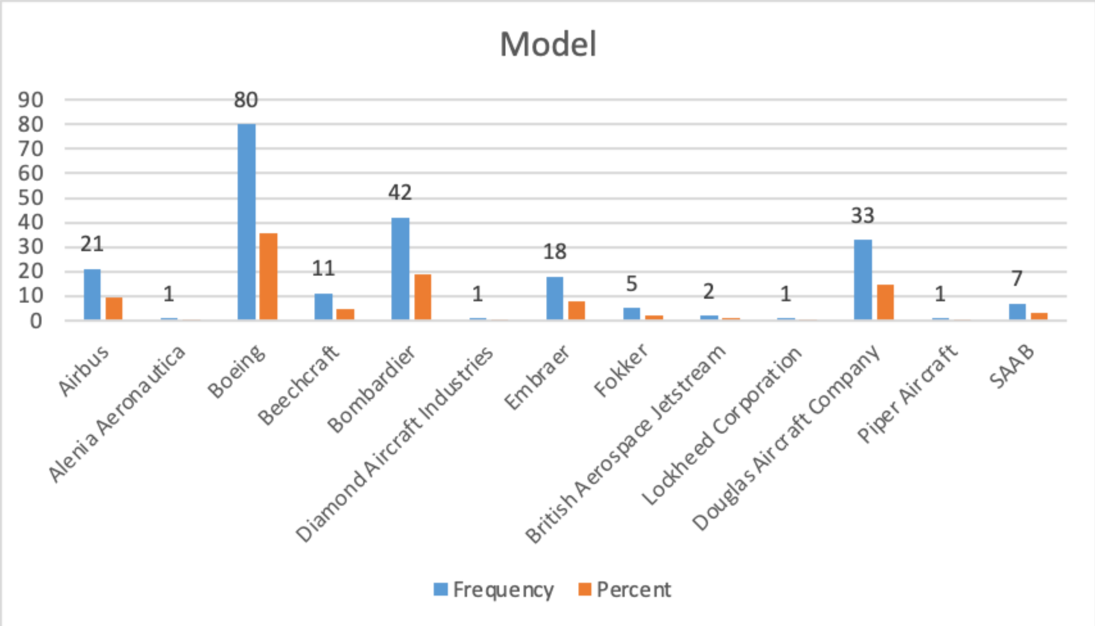
**Graphic 3.2. Operator Firm**




Graphic 3.2. displays the distribution of accident reports by the operator firm. Among the operators in this table, Delta Airlines is the operator firm with the most number of

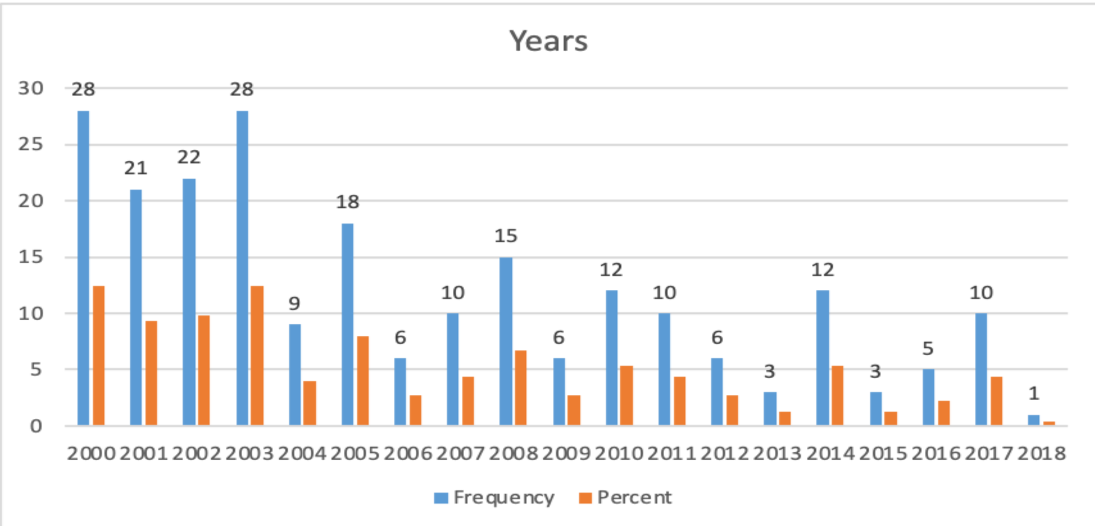
accident reports, which is 26. It is followed by American Airlines with 25 accidents, Northwest airlines with 17 accidents and Southwest Airlines with 15 accidents.

**Graphic 3.3. Model**



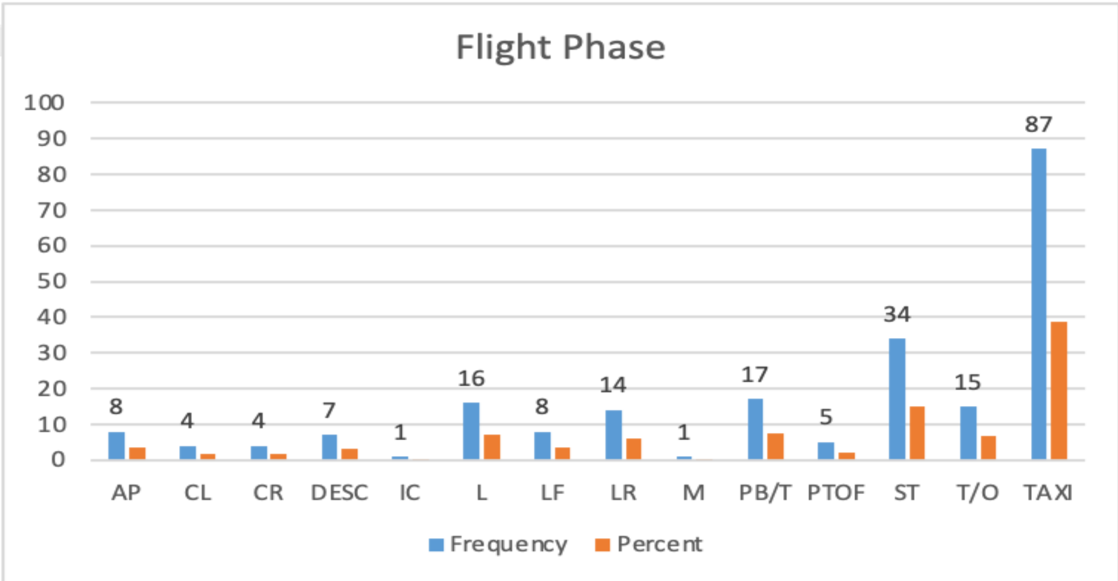

Among the 225 reports examined, Boeing was the aircraft brand with the highest number of accidents, with 80 accidents, followed by Bombardier with 42 accidents and Douglas Aircraft Company aircraft with 33 accidents.

**Graphic 3.4. Year**



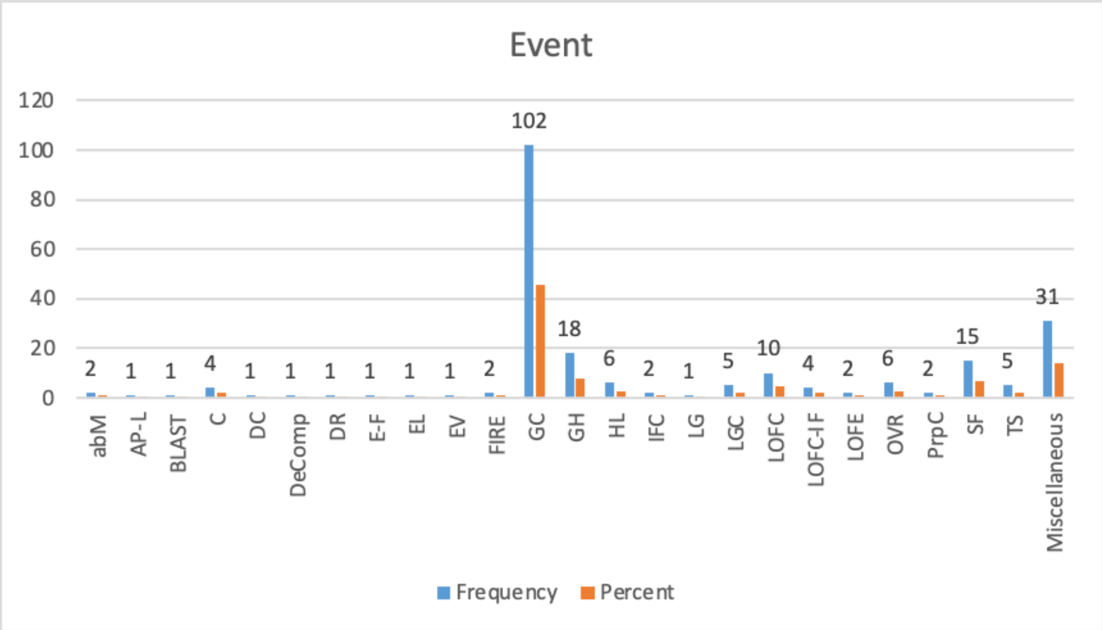
Among the aircraft accidents reports examined in the study, the most accidents were seen as 28 accidents in 2000 and 2003.  There does not appear to be another year that exceeds the number of accidents in each of the first 4 years. The total number of accidents in these 4 years is 99, which constitutes 44% of all accidents. The total number of accidents in the other 15 years is 126, which constitutes 56% of the total accidents. It can also be seen in the table that the number of the accidents has grown smaller as years pass. In 2018 only 1 accident which is the fewest number was reported.

**Graphic 3.5. Flight Phase**




Among the accidents examined, 221 reports were coded under the title Flight Phase. Most accidents occurred in the TAXI process with the number of 87 accidents. It is followed by ST which stands for Standing-engine with 34 (38.7%) and 17 PB/T which stands for Pushback/ Taxi (7.6%).

**Graphic 3.6. Event**




Among the reviewed reports, 225 accidents were identified under the Event title. Of these, a total of 102 GC (Ground Collision) is the main event that occurred during the accident.

### 3.2.3. Relationship Test

Relationship tests between were conducted using Chi-Square test and the results are shown below.

#### 3.2.3.1. Chi-Square Tests

Relationships between demographic information and human errors were tested using the Chi-Square test. Since the data obtained in the research were categorical, these relations were analysed with the chi-square test. In this test, degree of freedom (df) and significance were sought. The degree of freedom, which indicates the number of variants, is important in the interpretation of the chi-square test. This degree is expected to be equal to 1 less than the number of existing groups. In the tests examining the relationship between the two groups, the degrees of freedom is 2 -1 = 1. In order to reveal the significance of the relationship, the p value in the row of the degree of freedom is checked. ($p<0,005$) (Dündar, D. 1981; Mehta, C. R., & Patel, N. R. 2011).

In the table below showing the relationships between demographics and themes, only those with a significant relationship are shown.

**Table 3.5. Demographics X Other Themes**

| Demographics vs. Other Themes | Chi-Square | p |
|---|---|---|
| Accident Type vs. Policy&Process Issues | 19,88 | 0,002 |
| Accident Type vs. Maintenance Issues | 7,23 | 0,033 |
| Accident Type vs. FAA Issues | 13,19 | 0,021 |
| Accident Type vs. Manufacturer | 8,25 | 0,043 |

Policy & process issues ($p<0.01$), maintenance issues ($p<0.05$), FAA issues ($p<0.05$), and manufacturer ($p<0.05$) of fatal and non-fatal features appear to be associated with accident type which is one of demographic variables of the accidents. Among these relationships, the highest level of significance is between accident type and policy and process issues. In addition, policy and process issues is under the organizational theme, maintenance issues are under the HFACS-ADF extension theme, and FAA issues and manufacturer are under the non-organizational theme (H1 is partially accepted).

In the table below showing the relationships between all themes, only those with a significant relationship are shown.

**Table 3.6. Organizational Influences vs Other Themes**

| Organizational Influences X Other Themes | Chi-Square | p |
|---|---|---|
| Policy&Process Issues vs. Preconditions_Training | 46,833 | 0,000 |
| Policy&Process Issues vs. Teamwork | 5,837 | 0,047 |
| Policy&Process Issues vs. Maintenance Issues | 12,306 | 0,004 |
| Policy&Process Issues vs. FAA Issues | 11,927 | 0,012 |
| Policy&Process Issues vs. NOF_Manufacturer | 25,082 | 0,000 |
| Climate/Culture Influences vs. NOF_Manufacturer | 21,596 | 0,044 |
| Climate/Culture Influences vs. Supervisory Violations | 225,000 | 0,004 |

As seen in the table above, there is relationship between policy &process which is under the organizational influences theme and training ($p<0.001$), and teamwork which are under preconditions theme ($p<0.05$), maintenance issues which is under HFACS-ADF extension theme ($p<0.01$), FAA issues ($p<0$) and manufacturer ($p<0.001$) which are under Non-organizational factors theme. In addition, there is a relationship between the Climate/culture influences which is under Organizational influences theme and between manufacturer which is under non-organizational factors ($p<0.05$) and violations ($p<0.01$) which is under supervisory theme (H2 is partially accepted.).

# CHAPTER IV

# DISCUSSION, CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

## 4.1. Discussion and Conclusion

Over the past decades, aircraft were considered the most dangerous means of transport because of mechanical failures that led to increased accidents (Chen & Yu, 2018). However, studies suggested that human error was the leading cause of aircraft accidents in the modern era of aviation. The innovation in mechanical aircraft technology and increased reliability were directly tied to this discrepancy in the genesis of accidents. This approach has forced a bigger percentage of aviation companies to task their safety staff to design safety programmes to address this issue and frequently elusive human error issue in the last two decades. Different models and methods have been introduced to analyse and classify the increased importance of human-related factors in aircraft accidents. The framework for Human Factor Analysis and Classification System (HFACS) built an extensive, user-friendly instrument for diagnosing and classifying the human-related cause of aviation accidents (Chen & Yu, 2018). This framework has been incorporated in the military and public sectors in the United States and Canada. Also, its reliability has been demonstrated in various studies.

A significant part of HFACS applications in aviation entails analysis of accidents in the 20th century. However, the fact that the total number of commercial air traffic increased between 2000 and 2018 and that the share of mechanical errors in accidents decreased significantly with the use of the third and fourth generation aircraft, which were technologically advanced in these years, increased the importance of focusing on human factors between these dates (Chauvin et al., 2013). Based on this study, Demographic variables of the accidents between 2000-2018 in the USA and their relationship with the HFACS themes were revealed. And also, with the application of

HFACS 7.0 and HFACS-ADF, which are the latest versions of HFACS to aviation accidents in the 21st century, a more comprehensive approach has been displayed. Therefore, not only organisational factors but also non-organisational factors such as airport personnel and regulatory issues, which affect the accidents, were analysed.

Among the demographic variables analysed, accident type analysis shows that the number of the fatal accidents in 21$^{st}$ century is remarkably low in the USA with the rate of 3.6% of all accidents (Graphic 3.1). According to ICAO (2021, June) the last fatal accident was seen in 2009. This can be related to FAA regulations (https://www.govinfo.gov/content/pkg/FR-2013-07-15/html/2013-16849.htm) which was published in 2013 after the fiery accident killing 49 people in 2009. Examining the causes of the accident, it was determined that the fatigue and lack of training of the flight crew and this prompted federal laws mandating additional rest and training for pilots (FAA, 2020, July).

Another foremost point that is conspicuous according to Graphic 3.4 is that the rate of the accidents has grown smaller over the years which is consistent with the decreasing number of accidents throughout the world in the last two decades (ICAO, 2021, July). As mentioned earlier in the study, the advancing aircraft technology like the introduction of third and fourth generation aircraft and improving safety management systems and human factor analyses can be a major contributor to this decline.

Graphic 3.5 indicates that the most of the accidents took place during the taxi process which is another important result. It is supported by Graphic 3.6 that displays the occurrences happening during the accidents. It is seen in Graphic 3.6 that the main event in the accidents is ground collision that constitutes almost the half of the events. Ground collision is caused by two aircraft colliding with each other or a part of an aircraft touching another aircraft, a building, a ground vehicle, etc. on the ground. In addition, Human Factors Theme Statistics in the study (Table 3.4) shows 18% of the accidents include ground crew or airport personnel issues like the fuel truck driver's failure to maintain clearance with a taxiing airplane as a cause factor in the accidents (NTSB,2020, April). It can be concluded from these statistics that non-organizational factors, especially ground personnel issues should be taken into consideration more seriously.

Table 3.4 also shows that performance-based errors (13%) and decision-making errors (13%) are the categories coded most commonly on operational level. Similarly, Hulme, A., Stanton, N. A., Walker, G. H., Waterson, P., & Salmon, P. M. (2019) reported a total of 22 studies of HFACS based on 4,456 accidents. In regards to the weighted mean proportions, skill-based error which was updated as performance-based error in the latest version of HFACS (53.5%), decision error (36.5%) are the most frequently coded categories. It can be concluded that this research supports the idea that unsafe act of the flight crew has been the major cause of accidents throughout the years.

From relationship tests in the research, there are various contributors to aircraft accidents. Among the demographic variables, only accident type is related to human factors themes many of which are non-organizational factors including maintenance issues like maintenance personnel's improper use of procedures, FAA issues like inadequate procedure, and Manufacturer issues like design errors.

The relationship analysis results of human factors themes shows a relationship between policy and process, which falls under the organisational influences theme and training which falls under preconditions theme. Policy and process issues cover providing adequate organizational training. It means that unavailable or inadequate training of the staff in the organization might affect technical and procedural knowledge of the staff during the operation (DOD, 2014). Although unsafe acts are frequently linked to specific actions and decisions that are made at the discretion of the operators. The solution is training to help people enhance their skills and knowledge which can be achieved by proper training policy (Daramola, 2014).

Human errors, especially in the aviation industry, can be disastrous and cost the airlines a fortune through accidents. The changes in the modern age have led to significant human factors problems. Human factors play a significant role in aviation for saving lives and minimising organisations' expenditures (Cohen et al., 2015). Notably, with increased technological advancements, keeping the staff up-to-date with the technology is a must. There is a necessity for regular training on the changes in technology. The aircraft have changed over time, which means that their handling has also been affected. Without appropriate training, it becomes difficult to reduce air accidents. Thus, the industry needs to invest in constant training of the personnel, providing refresher courses to ensure the handling of aircraft is at par with the technology. From the past research on this topic, Kim and Yoon (2013) affirm that accidents in the aviation industry are highly caused by skill-based errors. These errors could be eliminated or reduced by frequent training of the staff to match the current trends in the industry.

Policy and process issues are also related to teamwork which is generally caused by poor leadership, inadequate task delegation, failure to effectively communicate during the operation (NTSB, 2020, April). According to Li et al. (2008), poor organizational processes at the top levels of the organization may lead to poor Crew Resource Management (CRM) which addresses teamwork. If the flight crew are not clearly guided by the organization's procedures and programmes, or their pace of workload is not assessed properly in these procedures and programmes, the lack of communication, poor leadership or lack of assertiveness may arise between the members of the crew that can cause an accident.

Other factors that contribute to these accidents include organisation and supervisory categories. When investigating the causes of accidents in the aviation industry using HFACS, poor leadership is cited as a fundamental cause of accidents. The aviation industry is very sensitive and requires utmost keenness. Competency and judgment mistakes may cause huge consequences. From the review, Shappell (2007) associates accidents with judgment mistakes, skill-based errors, and administrative and human crew abuse between-group layers. It shows that aviation accidents are caused by various factors that need to work together for a successful flight.

Environmental factors are also a major cause of aviation accidents, with both physical and technical conditions discussed in this paper. Both these factors should be considered before any aircraft is allowed to fly. The failure to consider these factors or results in accidents.

Maintenance issues in the aviation industry have also been highlighted to be a cause for accidents. Poorly maintained planes are bound to cause accidents. On the issue of maintaining ace, manufacturer errors can also be highlighted. There have been complaints of manufacturer errors on several planes that arise from the same planes causing accidents. Maintenance should be carried out without fail and by qualified individuals having proper training and suitable, well-designed equipment, being guided with the up-to-date documentation, correct supervision provided by the organization and manufacturer.

When it comes to aviation accidents, several factors are involved, as discussed in this paper. As the rising technology seeks to lower down such accidents, there is a need for thorough staff training and the need to follow the codes that govern the aviation industry. Furthermore, organizational factors and non-organizational factors that contribute to the accidents should be highlighted as well as the operational factors.

## 4.2. Recommendations

It has been seen during the data collection process in the study that it is necessary for countries to give more importance to reporting of the accidents and to reach an international standard since it is a crucial step for clarifying the causes of accidents and increasing flight safety.

In addition, one of the most important issues that can reduce the number of accidents and their effects is that organizations provide stronger preventive measures with their policies and strategies. Besides this organizational steps, it has emerged from this study that not only organizational factors but also non-organizational factors should be included in organizations’ safety policies.

In future studies, accidents taking place in different countries and cultural differences between countries can be examined. In addition, differences between countries' reporting standards may also be the subject of research.

## 4.3. Limitations

Since the examined reports in the research are only the USA accident reports, it limits making a generalization about all the accidents in the world. In addition, the accidents examined were reported in the standards of NTSB. These reporting methods may differ from country to country. Finally, since accidents examined starting from 2000, when HFACS model was developed, the fact that the accidents before this year were not examined is another limitation.

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# APPENDIXES

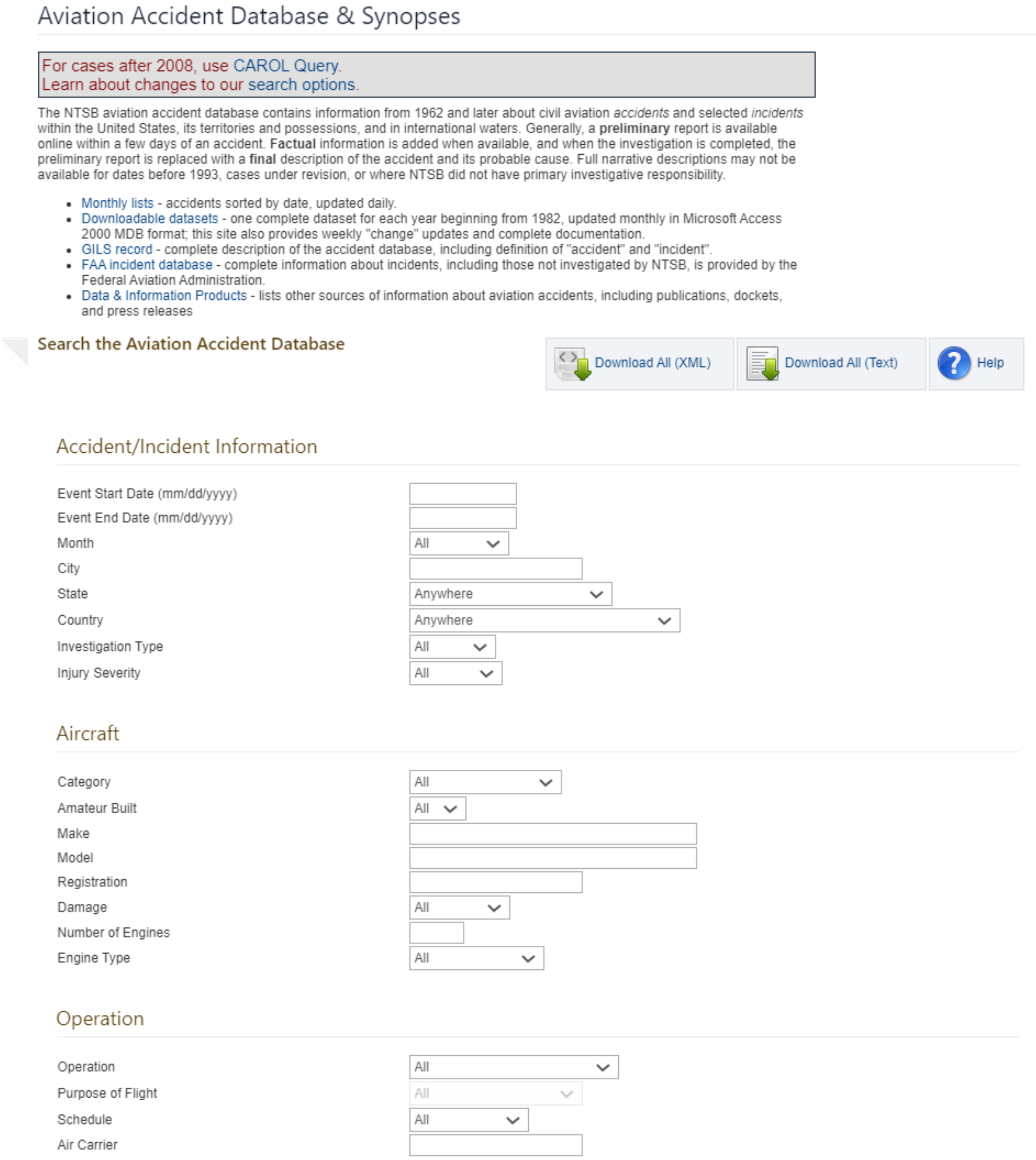
## APPENDIX A

Human Error Themes Used In The Research

| | |
|---|---|
| **Acts** | **Performance-Based Error** |
| | **Judgement&Decision-making Error** |
| | **Violations** |
| **Preconditions** | **Physical Environment** |
| | **Workspace** |
| | **Equipment** |
| | **Physical Problem** |
| | **State of Mind** |
| | **Sensory Misperception** |
| | **Mental Awareness** |
| | **Training** |
| | **Teamwork** |
| **Supervision** | **Inadequate Supervision** |
| | **Planned Inappropriate Operations** |
| | **Supervisory Violations** |
| **Organizational Influences** | **Resource Problems** |
| | **Personnel Selection&Staffing** |
| | **Policy&Process Issues** |
| | **Climate/Culture Influences** |
| **HFACS-ADF Extension** | **Maintenance Issues** |
| | **Airport Personnel** |
| | **ATC Issues** |
| | **Regulatory Issues** |
| **Non-Organizational Factors** | **Other Pilot Involvement** |
| | **FAA Issues** |
| | **Manufacturer** |
| | **Airport facility** |

APPENDIX B

The Web Page Used In Collecting The Data Of The Research



Aviation Accident Database & Synopses

For cases after 2008, use CAROL Query.
Learn about changes to our search options.

The NTSB aviation accident database contains information from 1962 and later about civil aviation *accidents* and selected *incidents* within the United States, its territories and possessions, and in international waters. Generally, a **preliminary** report is available online within a few days of an accident. **Factual** information is added when available, and when the investigation is completed, the preliminary report is replaced with a **final** description of the accident and its probable cause. Full narrative descriptions may not be available for dates before 1993, cases under revision, or where NTSB did not have primary investigative responsibility.

- Monthly lists - accidents sorted by date, updated daily.
- Downloadable datasets - one complete dataset for each year beginning from 1982, updated monthly in Microsoft Access 2000 MDB format; this site also provides weekly "change" updates and complete documentation.
- GILS record - complete description of the accident database, including definition of "accident" and "incident".
- FAA incident database - complete information about incidents, including those not investigated by NTSB, is provided by the Federal Aviation Administration.
- Data & Information Products - lists other sources of information about aviation accidents, including publications, dockets, and press releases

Search the Aviation Accident Database

Download All (XML) | Download All (Text) | Help

Accident/Incident Information

Event Start Date (mm/dd/yyyy)
Event End Date (mm/dd/yyyy)
Month: All
City
State: Anywhere
Country: Anywhere
Investigation Type: All
Injury Severity: All

Aircraft

Category: All
Amateur Built: All
Make
Model
Registration
Damage: All
Number of Engines
Engine Type: All

Operation

Operation: All
Purpose of Flight: All
Schedule: All
Air Carrier

APPENDIX C

The List Of The Abbreviations And Codes Used In Coding Process

***Accident Type:***

| | | |
|---|---|---|
| 1 | NF | Non-Fatal |
| 2 | F | Fatal |

***Model:***

| | |
|---|---|
| 1 | Airbus |
| 2 | Alenia Aeronautica |
| 3 | Boeing |
| 4 | Beechcraft |
| 5 | Bombardier |
| 6 | Diamond Aircraft Industries |
| 7 | Embraer |
| 8 | Fokker |
| 9 | British Aerospace Jetstream |
| 10 | Lockheed Corporation |
| 11 | Douglas Aircraft Company |
| 12 | Piper Aircraft |
| 13 | SAAB |

***Flight Phase:***

| | | |
|---|---|---|
| 1 | AP | approach |
| 2 | CL | climb |
| 3 | CR | cruise |
| 4 | DESC | descend |
| 5 | IC | initial climb |
| 6 | L | landing |
| 7 | LF | landing-flare |
| 8 | LR | landing-roll |
| 9 | M | maneuver |
| 10 | PB/T | pushback/tow |
| 11 | PTOF | prior to flight |
| 12 | ST | standing |
| 13 | T/O | take-off |
| 14 | TAXI | Taxi |

***Event:***

| | | |
|---|---|---|
| 1 | AbM | abrupt manoeuvre |
| 2 | AP-L | maintenance event |
| 3 | BLAST | blast |
| 4 | C | Collision between aircraft |
| 5 | DC | Compression problem |
| 6 | DeComp | Decompression |
| 7 | DR | Drag |
| 8 | E-F | Engine failure |
| 9 | EL | Emergency landing |
| 10 | EV | evacuation |
| 11 | FIRE | fire |
| 12 | GC | Ground collision |
| 13 | GH | Ground handling event |
| 14 | HL | Hard landing |
| 15 | IFC | In-flight collision |
| 16 | LG | Landing gear |
| 17 | LGC | Landing gear collapse |
| 18 | LOFC | Loss of flight control |
| 19 | LOFC-IF | Loss of control in flight |
| 20 | LOFE | Loss of engine power |
| 21 | OVR | overrun |
| 22 | PrpC | Propeller contact |
| 23 | SF | System failure |
| 24 | TS | Tail strike |
| 25 | Miscellaneous | |

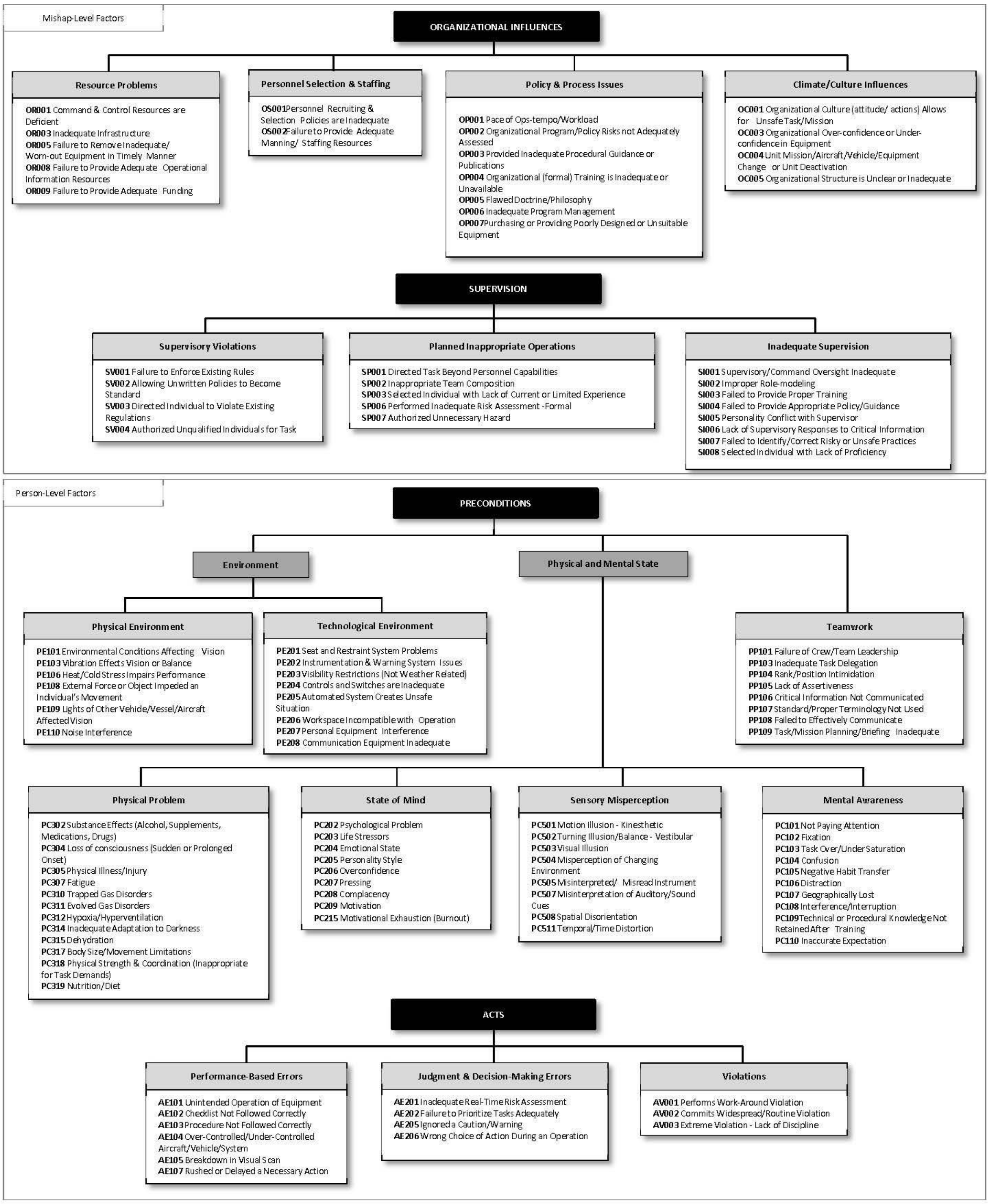
***Operator:***

| | |
|---|---|
| 1 | Aır Mıdwest |
| 2 | Aır Trans |
| 3 | Aır Wısconsın |
| 4 | Alaska |
| 5 | All Nıppon |
| 6 | Allegıant Aır |
| 7 | Amerıca West |
| 8 | Amerıcan |
| 9 | Amerıcan Eagle |
| 10 | Amerıcan Trans Aır |
| 11 | Amr Corporatıon |
| 12 | Astral |
| 13 | Atlantıc Coast |
| 14 | Atlantıc Southeast |
| 15 | Champlaın |
| 16 | Chatauqua |

| | |
|---|---|
| 17 | Chıcago Express |
| 18 | Colgan Aır |
| 19 | Comaır |
| 20 | Compass |
| 21 | Contınental |
| 22 | Corporate |
| 23 | Delta |
| 24 | Eagle Canyon |
| 25 | Era Avıatıon |
| 26 | Eva Aır |
| 27 | Executıve |
| 28 | Expressjet |
| 29 | Freedom |
| 30 | Frontıer Flyıng Inc. |
| 31 | Great Lake |
| 32 | Gulfstream Int'l |
| 33 | Hawaıın |
| 34 | Horızon Aır |
| 35 | John R. Ipson |
| 36 | Mesa |
| 37 | Mesaba |
| 38 | Mıdwest |
| 39 | N/A |
| 40 | North Amerıcan Aır Charter |
| 41 | Northwest |
| 42 | Pıedmont |
| 43 | Pınaccle Aır |
| 44 | Pro Aır Inc. |
| 45 | Psa |
| 46 | Republıc |
| 47 | Shuttle Amerıca |
| 48 | Skywest |
| 49 | Southwest |
| 50 | Sun Country |
| 51 | Transworld |
| 52 | Unıted |
| 53 | Us Aırways |
| 54 | Vanguard |
| 55 | West Fargo Bank Northwest |
| 56 | Wılmıngton Trust Co. |
| 57 | Wısconsın |

# APPENDIX D

## HFACS v. 7.0 Taxonomy and Nanocodes




22

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