FEDERAL UNIVERSITY OF RIO DE JANEIRO
COPPEAD GRADUATE SCHOOL OF BUSINESS
DÁRIO A. L. M. SANT'ANNA

HUMAN FACTORS IN OFFSHORE AVIATION COMPANIES: a Brazilian Case

RIO DE JANEIRO
2020

DÁRIO A. L. M. SANT'ANNA

HUMAN FACTORS IN OFFSHORE AVIATION COMPANIES: a Brazilian Case

Master's thesis presented to the COPPEAD Graduate School of Business, Federal University of Rio de Janeiro, as part of the mandatory requirements in order to obtain the degree of Master of Science in Business Administration (M.Sc.).

Advisor: Prof. Adriana Garibaldi de Hilal Ph.D.

RIO DE JANEIRO

2020

CIP - Catalogação na Publicação

SS231h Sant'Anna, Dário Antonio Leite Martins de
Human Factors in Offshore Aviation Companies: a Brazilian Case / Dário Antonio Leite Martins de Sant'Anna. -- Rio de Janeiro, 2020.
176 f.

Orientadora: Adriana Victória Garibaldi de Hilal.
Dissertação (mestrado) - Universidade Federal do Rio de Janeiro, Instituto COPPEAD de Administração, Programa de Pós-Graduação em Administração, 2020.

1. Human Factors. 2. Offshore Aviation. 3. Aviation Safety. 4. Organizational Culture. I. Garibaldi de Hilal, Adriana Victória , orient. II. Título.

Elaborado pelo Sistema de Geração Automática da UFRJ com os dados fornecidos pelo(a) autor(a), sob a responsabilidade de Miguel Romeu Amorim Neto - CRB-7/6283.

DÁRIO A. L. M. SANT'ANNA

HUMAN FACTORS IN OFFSHORE AVIATION COMPANIES:
a Brazilian Case

Master's thesis presented to the COPPEAD Graduate School of Business, Federal University of Rio de Janeiro, as part of the mandatory requirements in order to obtain the degree of Master of Science in Business Administration (M.Sc.).

Approved on February 12nd, 2020

Adriana Victoria Garibaldi de Hilal, D.Sc - Advisor
COPPEAD

Antonio Roberto Ramos Nogueira, D.Sc
COPPEAD

Ana Luiza S. V. Lopes, D.Sc
UNIRIO

ACKNOWLEDGMENTS

Throughout the writing of this thesis, I have received a great deal of support and assistance. I would first like to thank my thesis advisor Prof. Adriana Victoria Garibaldi de Hilal, D.Sc. of the COPPEAD Graduate School of Business, at Federal University of Rio de Janeiro, whose expertise was invaluable in the formulating of the research topic and methodology in particular. She consistently allowed this paper to be my own work but steered me in the right direction whenever she thought I needed it.

I would also like to thank the helicopter pilots from the offshore aviation sector who participated in this research project. Without their priceless contribution and input, the in-depth interviews could not have been successfully conducted.

I would also like to acknowledge Professor Roberto Nogueira of the COPPEAD Graduate School of Business, at the Federal University of Rio de Janeiro, as the second reader of this thesis, and I am gratefully indebted to him for his relevant comments and suggestions on this research study.

Finally, I must express my very profound gratitude to my parents, sisters, spouse, and son for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you very much.

RESUMO

SANT'ANNA, DÁRIO A. L. M. **FATORES HUMANOS NAS EMPRESAS DE AVIAÇÃO OFFSHORE: Um Caso Brasileiro**. Rio de Janeiro, 2020. 176 pp. Dissertação (Mestrado em Administração de Empresas). Instituto COPPEAD da Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2020.

O objetivo desta pesquisa é fornecer uma visão dos impactos dos fatores humanos no comportamento de segurança dos pilotos de helicópteros da aviação offshore no Brasil. Uma vez que entre 70% e 80% de todos os acidentes de aviação são atribuíveis ao erro humano em algum ponto da cadeia de causalidade, as tentativas mais eficientes de reduzir as taxas de ocorrências aeronáuticas são aquelas desenvolvidas com base na compreensão e aplicação de fatores humanos. Fatores humanos, como ciência multidisciplinar, se refere a compreender como as pessoas interagem com o mundo, suas capacidades e limitações, e a influenciar a atividade humana para melhorar a maneira como as pessoas executam suas tarefas (ICAO, 2018). Ao mapear esses fatores humanos e compreender suas implicações no comportamento de segurança dos pilotos, os gerentes e os profissionais de segurança da aviação teriam um melhor conhecimento do contexto do setor e das especificidades de suas empresas. A fim de investigar quais fatores humanos pilotos de diferentes níveis de proficiência e experiência percebem como os mais relevantes para a sua segurança, 16 pilotos de helicópteros foram entrevistados. Os resultados indicam que a situação atual da aviação offshore no Brasil é única e delicada. As empresas de aviação offshore demonstram, em certa medida, uma desconsideração por fatores humanos, especialmente quando estes fatores impactam negativamente a lucratividade. Portanto, essas organizações precisam abordar a segurança da aviação de maneira abrangente e meticulosa, se não quiserem ver as atuais taxas de ocorrências aeronáuticas produzindo uma frequência inaceitável de acidentes devido aos fatores humanos.

Palavras-chave: Fatores Humanos, Aviação Offshore, Segurança de Aviação, Cultura Organizacional, Fadiga, Estresse.

ABSTRACT

SANT’ANNA, DÁRIO A. L. M. **HUMAN FACTORS IN OFFSHORE AVIATION COMPANIES: A Brazilian Case.** Rio de Janeiro, 2020. 176 pp. Thesis (Master’s Degree in Business Administration) – COPPEAD Graduate School of Business, Federal University of Rio de Janeiro, Rio de Janeiro, 2020.

The objective of this research is to provide a useful understanding of the impacts of human factors on the pilots’ safety behavior in the Brazilian offshore aviation sector. Since between 70% and 80% of all aviation accidents are attributable to a human error somewhere in the chain of causation, the more efficient attempts to reduce the aviation accident rates are those that are developed upon a sound understanding and application of human factors. Human factors, as a multidisciplinary science, is about comprehending how people interact with the world, their capabilities, and limitations, and influencing human activity to improve the way people perform their tasks (ICAO, 2018). By mapping those human factors and comprehending their implications on pilots’ safety behavior, managers and aviation safety professionals would have a better knowledge of the context of the sector and their company specificities. In order to dive into which human factors pilots of different levels of expertise and experience perceived as the most relevant to their safety, 16 helicopter pilots were interviewed. The results indicate that the current situation of the Brazilian offshore aviation sector is unique as well as delicate. Offshore aviation companies demonstrate, to some extent, a disregard for human factors, especially when they negatively impact profitability. Hence, those organizations need to approach aviation safety in a comprehensive and meticulous way if they don’t want to witness current mishap rates producing an unacceptable frequency of accidents due to human factors.

Keywords: Human Factors, Offshore Aviation, Aviation Safety, Organizational Culture, Fatigue, Stress.

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF ABBREVIATIONS

ADS-B	Automatic Dependent Surveillance-Broadcast
ANAC	Agência Nacional de Aviação Civil (National Civil Aviation Agency)
ANP	Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (National Agency of Petroleum, Natural Gas and Biofuels)
ATSB	Australian Transport Safety Bureau
ASAP	Aviation Safety Action Program
CENIPA	Centro de Investigação e Prevenção de Acidentes Aeronáuticos (Center for Investigation and Prevention of Aviation Accidents)
CRM	Crew Resource Management
EASA	European Aviation Safety Agency
EUROCONTROL	European Organization for the Safety of Air Navigation
FAA	Federal Aviation Administration
FTL	Flight Time Limitations
FOQA	Flight Operations Quality Assurance
FRMS	Fatigue Risk Management Systems
HFACS	Human Factors Analysis and Classification System
HOMP	Helicopter Operations Monitoring Program
ICAO	International Civil Aviation Organization
ISO	International Organization for Standardization
JDME	Judgment and Decision-Making Error
LOFT	Line Oriented Flight Training
LOSA	Line Operational Safety Audit
MC	Main Contractor
NASA	National Aeronautics and Space Administration
NextGen	Next Generation Air Transportation System
NTSB	National Transportation Safety Board
OFDM	Operational Flight Data Monitoring
ORM	Operational Risk Management
PBE	Performance-Based Error
PSR	Perceived Safety Risk
QMS	Quality Management System
RNP	Required Navigation Performance
SMS	Safety Management System

SOP	Standard Operating Procedure
SPI	Safety Performance Indicator
TEM	Threat & Error Management
UK	United Kingdom
UKCS	United Kingdom continental shelf
UAS	Uncrewed Aerial Systems

CONTENTS

1. INTRODUCTION

1.1 Contextualization of the Problem

> "The point in learning about the human error is not to find out where people went wrong. It is to find out why their assessments and actions made sense to them at the time, given how their situation looked from the inside." (Dekker, 2002, p. 8).

This quote from Sidney Dekker portrays the importance of understanding the "whys" in aviation safety. In order to assess the impact of human factors in flight companies' performance, safety specialists should pay close attention to the task assigned to the aircrew, the tools that are at their disposal, and the environment surrounding them. According to Martinussen & Hunter (2017), aviation human factors can help the industry to understand and to predict the behavior of individuals in the aviation environment. Although that prediction is imperfect, it could be substantially beneficial. Predicting accurately how a pilot will react (behave) in certain circumstances will allow the industry to reduce pilot error by designing better aircraft and standard procedures that do not lead to incorrect reactions.

Although the concept of human factors might sound obvious, it is prudent to define the term in order to provide a common ground before we started our discussion about its impact on safety aviation. For this work, we are going to employ one of the definitions of human factors that have been widely accepted within the aviation industry, that one conceived by Jefferson M. Koonce. According to Koonce (2002), Human Factors is the study of the human skills, limitations, and behaviors and the integration of that knowledge into the design of objects, places, and environments in which people live and work for the improvement of the person's efficiency, safety, and general well-being. The first part of this definition includes the understanding of the human being, and the second one concerns the application of that knowledge in improving the human-machine system's performance and making people's lives better.

We should bear in mind that aviation human factors, as a multidisciplinary science, attempts to optimize the interaction between people, aircraft, and procedures that interface with one another within a work environment to achieve the organizational goals. Thus, aviation human factors encompass different fields of study, such as engineering, psychology, physiology, and medicine, just to name a few (Cusick et al., 2017).

In our globalized world, where distances between people have been shrunk by more efficient means of transportation and digital communication systems, the demand for flight has increased consistently over the last decades, leading to aviation industry growth at unprecedented rates. The numbers of flights and passengers are expected to grow consistently over the next decades, from 9.5 million in 2012 to 14.4 million in 2035 and from 0.7 billion in 2012 to 1.4 billion in 2035, respectively (Landry, 2018). That pace of aviation growth leads to an expanding workforce, which puts pressure on the flight companies to optimize training time and quickly produce skilled pilots. Meanwhile, technological developments are generating increasingly complex, automated systems that change the way aircrews interact with their aircraft. At the same time, the necessity to improve the air traffic management system is pressing researchers, industry professionals, and airlines. All these trends have considerable human factors implications (Salas & Maurino, 2010).

The leading human factor specialists and aviation researchers believe that between 70% and 80% of all aviation accidents are attributable to a human error somewhere in the chain of causation. This is why great efforts have been made to explain the relationship between human factors and accidents. Currently, modern aviation safety theory is heavily zeroed in on trying to understand the human decision-making process. It aims to comprehend how humans react to operational situations and interact with new technology and improvements in aviation safety systems. The way in which aircrew are managed affects their attitudes, which affects their performance of critical tasks. Consequently, their performance affects the safety and the economic results of the airline company (Cusick et al. 2017; Havle & Kilic, 2019).

Dekker (2015), also points out to the fact that more recently, recognition has grown that mishaps are inextricably linked to the malfunctioning of organizations and institutions. Frequently, people are not the instigators of failure; they are the recipients of it, the inheritors. In fact, Reason’s Swiss Cheese theory says that safety problems at the operational or sharp end are not necessarily created by the sharp end, but rather inherited by the sharp end.

In order to quantify and trend specific types of human error within aviation domains, Wiegmann & Shappell (2001) has developed a structured and standardized classification scheme that presents a comprehensive, user-friendly framework to assist practitioners in effectively investigating and analyzing human error in aviation. Their Human Factors

Analysis and Classification System (HFACS), a framework based on James Reason's "Swiss cheese" model of accident causation, bridges the gap between theory and practice in a way that helps improve both the quantity and quality of information gathered in aviation accidents and incidents.

Koonce (2002) argues that because a large number of aviation mishaps are attributable to the human factor, the more productive attempts to reduce the aviation accident rates are those that are developed upon a sound understanding and application of human factors. Hence, the careful use of the human factor knowledge, principles, and guidelines should make the training of pilots more effective, the evaluation of pilots more realistic, and improve the overall safety of flying.

When it comes to the offshore aviation in Brazil, the increase in the oil production chain along the Brazilian coastline, coupled with the recent pre-salt discoveries, has led to a rise in offshore helicopter operations. This new demand creates favorable conditions for the potential increase in the number of accidents in offshore air transport. Statistical data from Norway and the United Kingdom (UK) also show that over the past years, human factors have consistently been related to air accidents in offshore aviation. Nonetheless, successful initiatives in those same countries demonstrate that managing efficiently human factors may represent a substantial increase in offshore aviation safety, acting as a competitive advantage within the industry (Silva et al., 2011).

The accident investigation reports of those two reference countries show that human factors still are a significant contributing factor to offshore aviation accidents in the North Sea, representing 50% of the contributing factors. As to incidents, the results are quite similar - over 50% of the helideck incidents are associated with human factors (Oil & Gas UK, 2011; Norwegian Petroleum Safety Authority, 2017). When it comes to helicopter operations in Brazil, the most frequent contributing factors identified in accident investigations between 2008 and 2017 are directly related to human factors, which represent more than 55% of the total contributing factors of helicopter accidents (Brasil, 2018).

Helicopter offshore operations are, in many aspects, unique because pilots usually flight toward remote oil platforms and ships, and almost the entire flight occurs over the water. What’s more, it is very common that the final geographic position of the offshore destination varies, which adds even more risk and difficulty to the operation. We also should bear in mind that offshore helicopter pilots operate in a hostile environment, and therefore continuous improvement to mitigate risks is vital to the future of the aviation industry as a whole (Oil & Gas UK, 2011; Norwegian Petroleum Safety Authority, 2017).

Safety experts consider that the Brazilian offshore aviation sector is comparable to those of Norway and the UK (globally recognized as benchmarks within the industry) in terms of the scale of operations and geographic conditions. The Brazilian National Petroleum Agency (2018) and safety professionals from Brazilian offshore companies usually draw a parallel between the Brazilian offshore operation reality and international data so as to better understand the contribution of human factors to offshore helicopter mishaps. The assessment of the offshore aviation sector in those countries can contribute to grasping essential insights into the potential negative impacts of human factors on the safety behavior of companies' helicopter pilots and the challenges to mitigate those risks in Brazilian offshore operations.

Finally, like Brazil, both Norway and the UK have been experiencing a reduction in the offshore business over the last years, which may lead to pressure on safety through downsizing and a heavy focus on costs, both within the oil companies and the helicopter operators. Safety professionals are particularly worried about the adverse effects of cost reduction on the level of aviation safety. The prospect of new areas of exploration in even farther areas may introduce new and potentially more significant challenges to offshore aviation operations (Krakenes et al., 2017).

1.2 Purpose of the Study

This study explores the concepts of human factors and their key role in the safety of offshore aviation companies through qualitative research. Because of previous experience in the sector and the opportunity of access, helicopter transportation service companies that operate in the Brazilian offshore oil and gas production region were used as the basis for the analysis.

The data collected within those companies come from pilots of different levels of expertise and experience. As an exploratory study, this research aims to provide a useful understanding of the impacts of human factors on the pilots' safety behavior in the Brazilian offshore aviation sector. Furthermore, the study also contributes to creating valuable knowledge for the management of helicopter transportation service companies. Therefore, the research questions are formulated as follows:

What are the main human factors that affect pilots' safety behavior in offshore operations?
How can offshore aviation companies manage to mitigate the adverse impacts of those human factors on their pilots' safety behavior?

1.3 Relevance of the Study

When it comes to the interaction between the aircrew and the aircraft, human factors have a great deal to say about how aviation systems should be designed and managed. So as to meet the goals of reducing human errors, improving professionals' performance, and enhancing comfort to customers, an aviation system must accommodate the pilot's physical, sensory, cognitive, and psychological characteristics (Martinussen & Hunter, 2017). That is why the understanding of human factors in aviation can contribute to the development of even more efficient and operator-friendly systems whose final goal is to enhance the perceived levels of aviation safety.
In fact, the assessment of human factors is essential to all three aviation safety approaches – reactive, proactive, and predictive. In the reactive approach, human factors knowledge is applied to investigate previous mishaps as a way to prevent future ones. Therefore, finding, evaluating, and controlling human factors related hazards can contribute enormously to accident prevention. Because there are no longer a sufficient number of serious accidents to provide continuous and significant improvements to safety, aviation safety also requires a proactive approach. With the proactive approach, safety personnel can identify hazards that may not be obvious before they trigger an accident with disastrous consequences for the company. Finally, human factors analysis is paramount when it comes to predictive safety. It can help the investigation of potential hazards that do not yet exist, but that might cause damage the very first time they occur. Any successful effort to further lower flight accident rate will rely on tackling human factor related hazards before they present themselves (Stolzer et al., 2008; Cusick et al., 2017). The more decentralized control of flight trajectories and the increase of the number of aircraft flying in the sky will impose a considerably higher demand on the pilots' attention and information processing. In order to mitigate the risks associated with all these demands, the aviation industry needs to pay even more attention to human factors. If the aviation industry intends to accomplish a reduction in the aviation accident rate, aviation safety specialists need to address more effectively the human causes of accidents

(Shappell and Wiegmann, 2001). Therefore, the mastering of human factors knowledge can highly contribute to the aviation industry to face those significant challenges ahead (Salas et al., 2010).

All things considered, human factors are definitely a widely discussed subject in risk-sensitive industries, such as commercial aviation and nuclear power generation. However, as to offshore helicopter operations in Brazil, human factor concepts and frameworks are not yet consistently widespread among managers and aircrews or fully incorporated into companies' safety programs. For this reason, as an exploratory study with in-depth interviews, this research intends to investigate some critical human factors identified in the literature and the specific context of the Brazilian offshore aviation and, thus, to add to this understudied area. Furthermore, research results may be useful for both managers and pilots in the mentioned sector to prevent aviation mishaps due to human errors.

1.4 Delimitations of the Study

The present study is subject to certain delimitations. First, this study focuses on the operational aspects of specific helicopter transportation service companies. It aims to develop a broader view – the bigger picture, of the aviation safety within those companies. Hence, the financial aspects were not considered. Second, the main focus of this study is on pilots and copilots, and their behavior and interaction. That is why qualitative interviews were used to identify the main human factors that impact pilots' attitudes and behavior. Due to timely and financial restrictions, only voluntarily selected aircrew members were interviewed. Finally, the human factors analyzed in this study, such as decision-making and fatigue, are those considered more relevant in the aviation industry according to the literature review.

1.5 Study Structure

In order to usher readers through this research study and help them understand the results of the fieldwork, we will describe the summary of each part of this present work in the next paragraphs. In chapter 1, there is a brief background and the contextualization of the problem. The study introduction presents the first insights into the most relevant human factors in the offshore aviation domain. It includes the problem statement presenting the issues that will be explored in the study; the purpose of the study identifying what this research aims to achieve; the relevance of the study for both scholars and practitioners; the study limitations that can provide leads to future studies; and, finally, presents the way this work is organized.

In chapter 2, there is a review of the relevant literature about human factors and the offshore aviation main issues. This chapter is dedicated to the literature that supports this work. It explores the current knowledge concerning human factors in aviation, the situation of the offshore aviation sector, some of the theoretical frameworks of aviation accident investigation and safety programs, and the most modern tools available to mitigate the risks related to human factors. All this information is the base that supports the analysis of the research results.

Chapter 3 describes the research methodology used in this work and explains why a qualitative exploratory study is appropriate – Research methodology, which includes the type of research, introduces the companies studied, the research context, universe, sample and selection of subjects, data collection, presents the interview scripts, data processing and analysis, and comments regarding the limitations of the method adopted.

In chapter 4, the empirical results from the interviews are presented in order to promote greater clarity and understanding of the conclusions. These results are also compared and related to theories and frameworks previously discussed in the literature review.

Finally, chapter 5 draws the conclusions of this study with a discussion, final considerations and suggestions for future research.

2. LITERATURE REVIEW

The literature review was carried out through the university database where keywords, such as human factors, offshore aviation and aviation safety, were used to find relevant articles published on the most renowned international journals. Then, books by world-renowned experts at aviation safety, such as Dekker, Reason, Salas, Shappell and Wiegmann, were also consulted. Finally, manuals and reports from aviation agencies, such as ICAO and CENIPA, were also employed during the literature review. The list of those books and papers is available in section 7 – References.

In the following sections, the role that human factors play in aviation is discussed, the main frameworks of accident investigations are firstly described and then critically assessed. Secondly, the Brazilian offshore aviation sector is compared to the Norwegian and the British ones. Then, the most relevant human factors and their impact on the aviation industry are presented. Finally, the main tools and systems to mitigate the negative effects of human factors on aviation safety are summarized.

2.1 The Impact of Human Factors in Aviation

2.1.1 Human Factors in Aviation

In order to assess the impact of the study of human factors on safety aviation over the last decades and its prospective contribution to the industry, we should first evaluate the current status of the aviation industry in terms of safety and how the upcoming innovations could completely change the way we will be flying in the near future.

The aviation industry is already known for its meager accident rate of about one in one million operations. However, current projections indicate that by the middle of the next decade, the air transportation system will become even more complex and complicated. The volume of flights is projected to grow exponentially due to the consistent increase in demand. The systemic complexity is expected to skyrocket with the addition of very light jets, uncrewed aerial vehicles, and super large aircraft, such as the Airbus 380 (Salas et al., 2010).

Due to the workload placed on controllers in high density sectors and the projected increase in traffic demand brought about from passenger travel and e-commerce transport at the start of the millennium, the number of aircraft estimated to be operating in the U.S. National Airspace System in 2025 is likely to exceed the capacity of the current air traffic management system. The air navigation infrastructure will reflect a transformation of the current, radar-based system to a state-of-the art, satellite-based system for improving the efficiency, security, maintenance, and safety of the airspace (Landry, 2018).

Therefore, it is fair to say that the current accident rate is very likely to produce an unacceptable frequency of accidents somewhere around the beginning of the next decade that could cause immense damage to the business of aviation as a whole. That is why if the aviation industry wants to sustain the public’s Perceived Safety Risk (PSR) at low levels, safety aviation must continue to improve beyond the current standards (Salas et al., 2010).

We should first mention that since the late 1950s, all the initiatives to reduce the accident rate has generated unprecedented levels of safety. The aviation industry has invested sizable resources in improving the design and reliability of modern aircraft. One of the consequences is that today it is likely safer to fly in a commercial airline jet than to drive a car or walk across any cosmopolitan city in the world. Still, it is interesting that whereas experts can recount in detail the strides that the aviation industry has made over the last seventy years, one fundamental question remains unanswered: "After all, why do aircraft still crash?" (Wiegmann et al., 2001).

The answer may not be as straightforward as we might think or desire. At the beginning of the history of aviation, the aircraft was pointed out as responsible for the majority of accidents. The first aircraft were perceived as an intrinsic high-risk means of transportation. Nonetheless, the recent technological developments in the aviation industry have led to a completely different reality. New materials used in aerospace composite structures and powerful and dependable turbines, among other innovations, have contributed to the drop in the participation of technical failures in the causes of air accidents. This has brought the aviation industry to a new status quo where estimates in the literature indicate that somewhere between 70 and 80 percent of all aviation accidents can be attributed, at least in part, to human error and only a small percentage to mechanical failures or a design flaw (Wiegmann et al., 2001).

It is generally agreed that the remarkable decline in airline accidents from the 1950s through the 1980s was primarily attributed to those advancements in technology. However, as the safety benefits from technology began to some extent to saturate, new airline accidents started to call aviation experts' attention to the field of human factors. This shift of perspective in the assessment of the human factors has given rise to the study of the human-machine interface as well as human-human interactions and their impact on systemic safety (Salas et al., 2010).

As a matter of fact, the field of human factors in aviation has improved a lot over its short history. From an incipient interface between engineering and psychology, contemporary human factors have evolved to a multidisciplinary field that represents the methods and principles of the behavioral and social sciences, engineering, and physiology so as to optimize human performance and reduce human error. Just as the performance and safety of a general system can be degraded because of inferior hardware or software design or inadequate operator training, so too can the aviation system effectiveness be drastically reduced by errors in the design or the management of crew and organizational resources (Anca et al., 2010).

The careful application of the human factor knowledge, principles, and guidelines in aviation should dramatically improve aircrew training programs, pilot assessment process, and overall safety of flying. As previously mentioned, since a large proportion of the aviation accidents are currently attributable to the human factor, a considerable portion of the aviation accidents and incidents could have been prevented through the application of those principles of human factors. Thus, by better understanding and applying human factors concepts, airline companies can achieve more significant results regarding the reduction in aviation accident rates (Koonce, 2002).

When it comes to accident investigation, as the aviation industry matured and its technology improved, safety attention was focused on individual human factors and team performance issues in addition to technical factors. Consequently, accident investigation reports started to reflect more frequently and consistently issues related to crew coordination, communication, fatigue, and adherence to policies and procedures. More recently, attention has been focused on the additional role of organizational factors (organizational goals, policies, procedures, practices, training, and institutional rewards, just to name a few) in accidents, generating a corresponding concern with organizational safety culture. (Salas et al., 2010).

As we mentioned in the first paragraph of this chapter, currently, aviation has entered a revolutionary period, which will pose substantial challenges to airline companies' managers. This revolution has been supported primarily by two main developments. First, future traffic and congestion problems are forecasted to grow exponentially, especially in some regions of the world, such as the Pacific Rim. In other areas, such as the east coast of the United States and most of Europe, congestion appears to be so high that further growth, although demanded, seems to be even more challenging and complicated. Second, satellite navigation has enabled aircraft separation from other aircraft and from weather to be accomplished without relying on air traffic control, which is limited by the imprecision of its ground-based radar system. To sum up, the first one of these developments has created an increasing demand, and the second one has suggested a possible solution to the current centralized control of flight routes (Salas et al., 2010).

Therefore, the next generation of the airspace program in the US, a Federal Aviation Administration (FAA) initiative called Next Generation Air Transportation System (NextGen), calls for a variety of new concepts of operations as well as supporting technologies, such as self-separation, data-linked messages, closely spaced parallel operations and so forth. The FAA has led this modernization of the American air transportation system to make flying even safer, more efficient, and more predictable. NextGen aims at the transformation of the National Airspace System through satellite-based air traffic management and technological innovations that will enhance trajectory precision, communications, and weather forecasting. Included in this new infrastructure will be a shift of some roles and responsibilities from the ground to the air. Implications of NextGen changes for flight crews are likely to be profound, and much, if not most recent, aviation research has been directed toward these issues (Vidulich et al., 2014; FAA, 2019).

NextGen programs include satellite surveillance, Required Navigation Performance (RNP), and the Automatic Dependent Surveillance-Broadcast (ADS-B) system. It aims to transform the air traffic control system from a radar-based system to a satellite-based one with GPS. The program's priorities include multiple runway operations, nonvoice data communication, performance-based navigation, surface operations, and data sharing (Cusick et al., 2017).

Similar airspace control systems, including the ADS-B technology, have been developed in other countries as well. ADS-B offers significant operational improvements over well-known transponder (secondary radar) networks, such as increased situational awareness for pilots and controllers. Air and surface operations are safer by better monitoring accuracy, refresh rate, and intent information - all for a fraction of the cost of traditional surveillance systems (Brasil, 2018; Jazzaero, 2019).

In Brazil, the ADS-B implementation plan has begun in the country's leading oil and gas area – Campos Basin, due to the heavy traffic, consisted exclusively of rotary-wing aircraft. The continued growth of offshore aviation has required a more optimized use of on-site airspace. Responsible for more than 80% of oil extraction in the country, the Campos Basin covers 115,000 square kilometers, where dozens of offshore platforms extract about 1.5 million barrels of oil and 22 million cubic meters of gas per day. The magnitude of this production naturally requires a massive logistics operation, which is reflected in the air transport of personnel and supplies between the continent and the platforms: about 120 daily flights, covering long distances between the Rio de Janeiro coast and the platforms. Since 2017, Campos Basin airspace is 100% monitored by ADS-B receivers, and only aircraft adequately equipped with ADS-B transmitters may enter. (Brasil, 2018; Jazzaero, 2019).

In addition to the extension of the scope of aerial surveillance (Radar and ADS-B) and Flight Information Service (VHF communications), the restructuring of the airspace control in Campos Basin will, therefore, also provide several benefits. These include increased pilot situational awareness, the regularity of air operations, and accessibility to platforms. Not to mention improving weather information with the availability of eight new Automatic Surface Weather Stations (Brasil, 2018).

This new era of air transportation systems will severely affect pilot workload. It is generally agreed that pilots cannot manage the extra workload without the support of significant levels of automation. It is vital that we be aware that added layers of automation can sometimes also enhance the pilot's workload and decrease situation awareness (Salas et al., 2010).

This possibility may sound counterintuitive, but let's consider some aspects of automation. It is true that well-designed automation reduces workload and relieves attentional resources to concentrate on other tasks. However, the imperious need to manage the automation proficiently, particularly when involving data insertion or retrieval through a keypad, sets additional tasks to the pilot that can also increase his workload. In contrast, inadequate automation can reduce the pilot's situational awareness and create significant workload challenges when systems fail. That is why data entry errors and loss of situational awareness have become areas of increasing concern, and terms such as mode confusion,

automation surprise, and automation complacency were coined to express the emerging issues. (Landry, 2018; Skybrary, 2019).
The research on aviation crew behavior and performance is paramount to better understand and thus mitigate the human error in aviation accidents and incidents. Advances in flight simulation technology, training design, and crew resource management have consistently contributed to reducing the level of human error in the aviation industry. However, there is still much to be done, particularly concerning the evaluation and assessment of such programs in order to ensure their continuing effectiveness (Salas et al., 2010).
Based on projected increases in civilian commercial aircraft, Boeing predicts that 460,000 new commercial pilots will be needed worldwide by 2030. The International Civil Aviation Organization (ICAO), using a different methodology, found Boeing's 460,000 estimates to be conservative. Indeed, the ICAO predicts a worldwide shortfall of approximately 25,000 pilots per year between 2010 and 2030. These projections do not take into account the demand for operators of uncrewed aerial systems (UAS), which could be substantial. It is unclear if the future UAS operators will be individuals with little interest in a career as an airline pilot or drawn from the ranks of rated pilots aiming for a career in the airlines. If future UAS pilots are drawn from the pilots interested in airline careers, the increasing number of UAS operators will exacerbate the shortages predicted by Boeing and the ICAO (Weissmuller & Damos, 2014).
To summarize, the human factor aspects of aircraft accident investigations should be improved. Air-safety investigators need to be provided with a better understanding of human factor issues and analytical techniques. Regardless of the tool, safety efforts cannot be systematically reoriented until a comprehensive understanding of the nature of human factors in aviation accidents is accomplished. Such knowledge can only be derived from an in-depth analysis of existing accident databases. Hence, to achieve these objectives, safety aviation should count on a robust human error framework, in addition to new investigative methods and reliable accident databases (Shappell & Wiegmann, 2001).

2.1.2 Models of Accident Causation

The primary source of information to Safety Aviation are incidents and accidents. From their analysis researchers and accident, investigators try to find out the causes or the contributing factors in order to learn from these events and therefore prevent similar ones from happening in the future. However, this is not a trivial task. According to Shappell and Wiegmann (2001), although, there has been a proliferation of human error frameworks over the recent years, experts have struggled to find out which framework or method they should use so as to conduct their comprehensive human error analysis of aviation accident data and provide a structure around which new human factors investigative techniques can be designed. In fact, the choice of the most adequate and reliable method or framework to assess accidents is fundamental for the comprehension of the underlying causes of accidents and the solutions to improve system safety (Fu et al., 2017).

Sidney Dekker (2014) argues that an aviation safety expert conducts a safety program based on the sources of risks he perceives as the most dangerous to the organization. That, in turn, depends on what the organization's accident model is. That is why accident models are crucial to define and mitigate the most critical risks in an airline company. There are plenty of options in the literature that were developed to help investigative efforts. In reality, the scientific literature has presented many accident models to the aviation industry over the last decades. Figure 1 shows four of the most employed contemporary accident models, or perhaps more correctly said, families of accident models.

Accident Model	Risk Defined as	Major Threat to Safety	Manage Safety by
Chain of events	Weakest link in the chain	Unreliable humans	Getting rid of weakest link
Barriers (Swiss Cheese)	Accident trajectory not stopped	Weak defenses	Plugging holes
Systems theory	A control problem	Complexity and goal conflicts	Making goals and erosion visible
Drift	Gradual acceptance of lower margins	Being successful	Staying chronically uneasy

Figure 1. Dekker's classification of accident models. Note. Adapted from Dekker, 2014.

2.1.2.1 Chain-of-events, the domino effect

The Chain-of-events model appeared in the 1930s derived from the idea of "triangle," which was conceived by H.W. Heinrich. It is one of the most known and employed tools to research and analyze accidents in aviation. The central concept is that a linear series of errors, failures, and even violations is necessary to push a system towards the verge of a breakdown (figure 2). In order to make the model more palatable and easier to understand, experts make an analogy with a line of dominoes. When one piece falls against the next one, it provokes a cascade effect, dropping all dominoes, until the last one is also down (Dekker, 2014). The only way to prevent that sequel of failures from happening and consequently causing a mishap is to remove one of the dominoes from the line. Due to its robust association with dominoes, the chain-of-events model is taught in many schools of safety aviation as a basic concept.

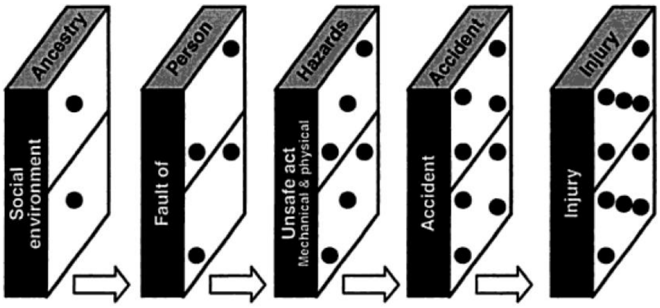

Figure 2. Domino model. Note. Adapted from Hollnagel, 2004.

The logic behind the chain-of-events is also based on a proportional relationship between major accidents/fatalities, injuries and incidents, and minor events – the triangle. In other words, there are many common causes of incidents and accidents. By making an effort to reduce minor incidents, the organization is also avoiding accidents because they share many common contributed factors. Combating the causes of incidents is an indirect approach to decrease the rate of accidents and fatalities in aviation. This concept explains the painstaking efforts of safety experts to mitigate minor mishaps so as to reach the causes of a latent accident. Despite the broad acceptance of this model within the aviation community over the last decades, more recent research has shown that the safer your industry becomes, the less applicable the common cause hypothesis becomes. It means that when a company reaches a certain level of aviation safety, the triangle approach will make no more sense because incidents in very safe systems are caused by radically different things than accidents or fatalities. (Dekker, 2014).

2.1.2.2 Barriers

Barrier models propose that our safety-critical activities are generally well protected against risk. We have both hard and soft defenses (or barriers) in place, consisting of, for example, blast walls, or procedures. A lot needs to go wrong for a failure to happen in these systems. The last line of defense is often thought to be the human operator at the sharp end. The barrier model is inspired by industries where containing (dangerous) energy is the primary safety issue, for example, process control, oil & gas, nuclear power generation. Large-scale industrial accidents during the late 1970s and 1980s inspired the creation of the model. Barriers models assess accidents as an effect of the combination of active errors or “unsafe acts,” committed by those on the sharp end of a system; and latent errors, or conditions buried inside the organization that lies dormant for a long time but can be triggered in a particular set of circumstances. (Dekker, 2014).

The given role to "unsafe acts" is vital in this model—people need to do something wrong or unsafe at the sharp end for all the bad energy to breach the final barriers. Once again, this seems to invoke ‘human error' as a final and necessary cause, and the human as one of the weakest links. This means that while the model helps find and categorize accident precursors or contributors in the rubble after a mishap, it is more difficult to make meaningful predictions with it. What is much harder for a barrier model to do is to explain the social, organizational, and bureaucratic context that gave rise to weak defenses. (Dekker, 2014).

The most known barrier model is the James Reason’s Swiss Cheese model of accident causation, which has made huge strides towards an investigation into organizational contributions to accidents and incidents since 1990. Experts have adopted this model, companies and world regulatory agencies such as ICAO, the global aviation body, as the basis of their investigative efforts and understanding of accidents (Griffin et al., 2015).

Reason has identified several layers (barriers) within which ‘holes’ (potential failures or errors) are always present. The alignment of those holes can result in an accident (Figure 3). In the majority of the cases, at least one layer will stop an event resulting in a catastrophe. Since an organization is a dynamic system, the holes in the Swiss cheese are fluid in the sense that they may appear and disappear or even change their size, depending on the psychopathology of the organization. A crucial aspect of Reason's model is the difference between the latent errors and the active errors of those at the ‘sharp end’ of the system (Griffin et al., 2015).

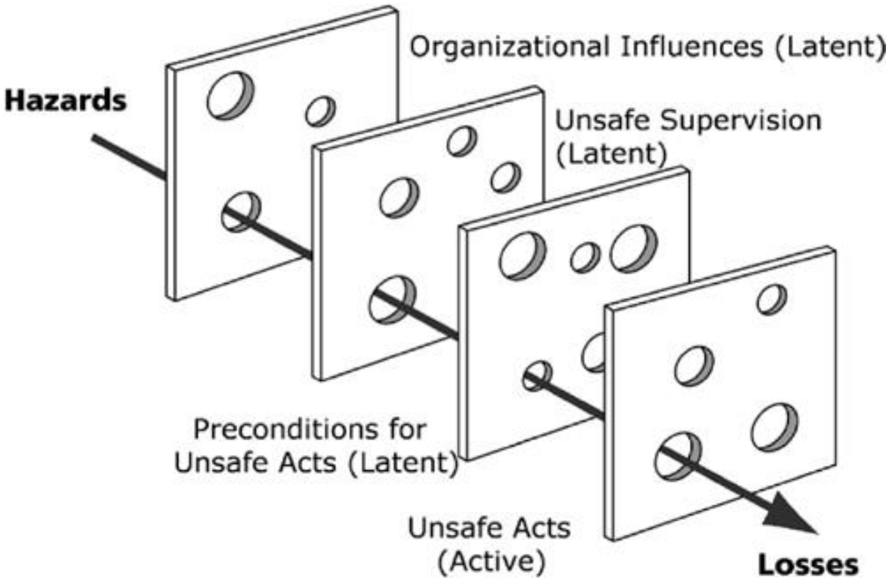

Figure 3. Reason's Swiss cheese model of accident causation. Note. Adapted from Griffin, 2015.

The model predicts that due to the existence of its barriers, most of the active failures will be caught and not lead to adverse outcomes. However, this point of the model may highlight a major problem of Reason's work, which is that without a predictive element, some active and latent conditions will continue to exist and may eventually result in an accident. This tends to limit the model's applicability to a post-accident investigation into the pathology of an organization rather than a context-specific and applicable method of investigating all precursors to an incident or accident before or after the event. Despite its limitations, this model has made significant advancements in the field of human error investigation and drew the attention of investigators and companies away from solely studying and blaming individuals (Griffin et al., 2015).

2.1.2.3 Systems Theory

According to Dekker (2014), the mindset in the aviation industry that defenses are the best investment in safety has led to an increase of complexity in many organizations. More defenses mean more engineered systems, more procedures, more paperwork, more managers, more pilots, more mechanics, more connections, and more activities. The interactions of those actors are a sine qua non condition for aviation safety.

However, the other side of the coin is that the more complex an organization, the more difficult it becomes to control. The system theory tries to deal with this problem of complexity in a quite complicated environment – aviation. Complexity frequently leads to a system that is difficult to comprehend entirely. It is full of unexpected interactions and interconnections. The more complex an organization, the more challenging it becomes for managers even to realize whether they still have adequate control or not. Therefore, system accidents result not from component failures, which might happen, but from erosion of control of safety-related constraints on the development, design, and operation of the organization.

2.1.2.4 Drift

This model fights against a tendency to complacency in some organizations after some time without the occurrence of a relevant mishap. In that situation, managers gradually start to accept low margins of safety. This is quite worrisome when it is associated with an unawareness of a specific danger within the organization. Complacency defines many of the risks. The drift model was the first to see accidents as the result of a drift into failure, and to focus on the organizational aspects to explain that trend. This theory is a tool to understand an accident not as a sudden episode where energy was not contained, but as an episode over time, where people and the whole organization subtly change their idea of what was risky in the first place (Dekker, 2014).

2.1.2.5 Modern Approaches

More recently, Gui Fu (2017) proposed another way to comprehend accident models. The accident causation theory gathers the classical, modern, and contemporary accident causation chain, according to the depth of analysis. The classical accident causation chain assesses accidents from two viewpoints: individual error and mechanical reasons. The modern accident causation chain adds management and education factors as the root cause. However, these models actually do not give specific explanations for the management factors, which makes them more difficult to be employed for practical accident analysis. As an evolution of the previous theories, the contemporary accident causation chain

classifies management factors into several categories, which is helpful for practical application.
The contemporary causation chain was the base for the development of the Swiss Cheese model, already mentioned in this work, created by James T. Reason in 1990; the 24Model, proposed by Fu in 2005; and the HFACS, devised by Shappell and Wiegmann in 2000. The HFACS, currently one of the most famous and applied models in the aviation industry, was, in fact, established from the ‘‘Swiss cheese" model. They share many fundamental concepts. As to the relatively new 24model, it has become a more common accident cause analysis method, especially in southeast Asia. (FU et al., 2017).
The accident causation model developed by Fu is referred to as the accident causation “2–4” model or the 24Model. The 24 Model proposes the viewpoint that all the human and organizational factors involved in an accident should be systematically and comprehensively analyzed. This model describes the human and organizational factors related to an accident at four levels (Fu et al., 2016). The 24 Model was successfully adapted to analyze accidents across a wide range of domains, such as mining accidents and chemical accidents. This model provides a new approach to organizational accident analysis. The 24Model is a useful framework for conducting accident analysis. However, it needs to be further optimized according to the sector of the aviation industry that is being analyzed (Xue & Fu, 2018).
As to the 24Model, it highlights how organizational factors and individual factors contribute to accidents. It divides the causes of accidents into two groups, the internal organizational factors, and external organizational factors. The internal organizational factors are represented by two levels, the individual level and the organizational level (Figure 4). The individual level is divided into two phases, habitual behavior and one-off behavior and conditions. The organizational level is also divided into two phases, guiding behavior and operating behavior. Habitual behavior includes the lack of safety knowledge, shortage of safety awareness, bad safety habits, and poor physiological status, and one-off behavior and conditions that refer to unsafe acts and unsafe conditions. Guiding behavior refers to the defects of organizational safety culture, and operating behavior refers to the flaws of the organizational safety management system. Although the 24Model has presented considerable improvements in the aviation accident investigation field, such as the organization and individual behavior control methods, and the case training system of controlling individual behavior in accidents, the practicability, and applicability of the

model should still be proved in practical applications of accident investigation and analysis (Fu et al., 2017).

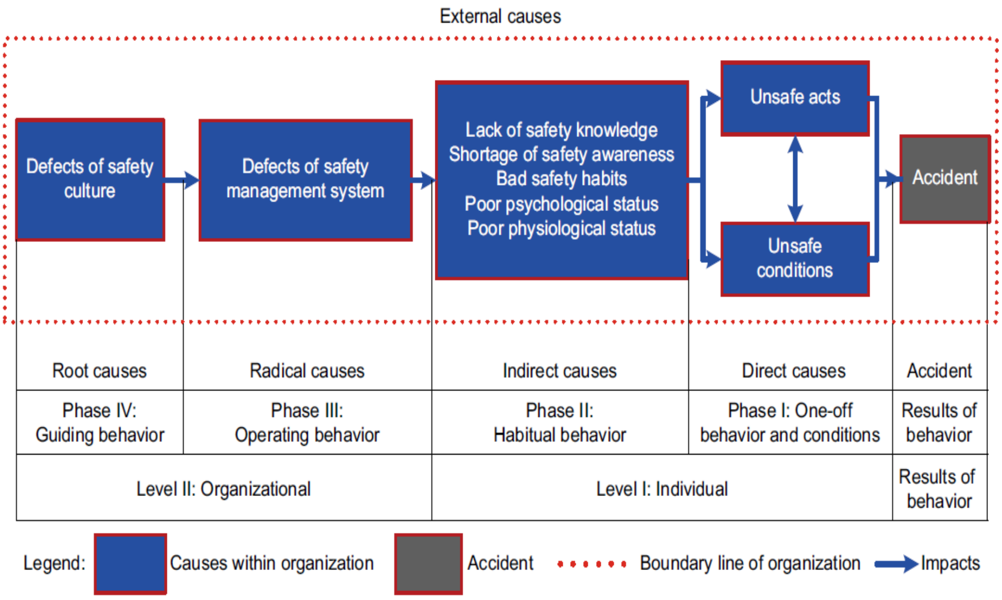

Figure 4. Accident causation ‘‘2-4’’ model (24Model). Note. Adapted from Fu et al. (2016).

In the HFACS model, Shappell and Wiegmann (2001) defined the latent failures and active failures in Reason’s Swiss cheese model and described the holes of four level failures: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. They presented the HFACS model after analyzing thousands of aviation accidents caused by human factors. In fact, HFACS provides a framework for applying Reason’s ideas and theory. One of the critiques related to the model is that it explains the causal factors of the accident but does not give the corresponding implementing measures to predict and eliminate causes (Fu et al., 2017).

Fu et al. (2017) also argue that in HFACS, the cause classification is more practical, and the accident analysis process is more convenient than those of other models. On the other hand, the 24Model includes external factors, which makes the cause analysis more systematic and comprehensive. What’s more, the 24Model puts forward more corresponding measures to prevent accidents. Since HFACS was proposed based on Reason’s ideas and theory and developed by employing aviation data, it is more suitable and applicable to the aviation industry than the Reason’s Model.

Xue & Fu (2018) claims that, with the systematized development of management methods in the global civil aviation industry, the original HFACS is no longer able to fully identify the human and organizational factors involved in civil aviation accidents. The shortage of the original HFACS is mainly because of its incomplete identification of organizational factors in civil aviation accidents. The original HFACS separates management factors into three independent modules: resource management, organizational climate, and organizational process. However, these three subcategories are not sufficient for characterizing the safety management status in the current civil aviation industry, such as risk analysis, learning from experience, and change management.

Nonetheless, the practicability and applicability of the 24Model should be tested by more practical applications of accident investigation and analysis (Fu et al., 2017). Havle & Kilic, (2019) also argue that HFACS is highly useful for accident analysis in aviation due to the fact that it is the most widely used analytical framework in the literature for investigation of human errors contributing to accidents in various disciplines and industries such as the maritime industry, mining, healthcare, oil and gas, railways, and aviation. Furthermore, world-renowned aviation organizations, such as the FAA and the Australian Transport Safety Bureau (ATSB), have also employed HFACS to investigate the causal factors of accidents and incidents and underlying factors that might affect safety negatively.

2.1.3 Human Factors Analysis and Classification System (HFACS)

As we mentioned in section 1.1, modern safety theories and advancements in technology have led the aviation industry to new methods of safety investigation. Aviation safety experts have shifted their attention from mechanical malfunction and skill-based human error towards underlying human factors, such as organizational issues, adverse mental situations, and the decision-making process. The next generation of aviation will impose considerable challenges to the industry, in particular to pilots. The rise of complexity and density levels in air traffic has the potential to introduce new types of human factors risks into the aviation system. Therefore, the comprehension and detection of emerging human factors risks are paramount to reduce the number of accidents beyond the current levels. By being the primary sources of information to safety researchers, accident and incident investigations can hence indicate trends in human factors and causal factors, which will act as early warning signs of growing risks (Yan & Histon, 2014).

In order to perform all those accident and incident investigations, safety experts should overcome the problem that human error is much more complex and intangible than the well-defined situational and demographic variables. That difference makes it difficult to apply an investigative methodology that is both easily understood and universally accepted. Without a structured and standardized classification scheme, investigators will have to work with little more than narrative reports of the event, making it practically impossible to quantify and trend specific types of human error (Shappell et al., 2007).

In section 1.2.5, we mentioned that Shappell's and Wiegmann's HFACS is derived from the Swiss Cheese Model, which shows the dynamics of accident causation. The HFACS framework was initially developed for the United States Navy and Marine Corps as an accident investigation and data analysis framework. The FAA, like other aviation organizations, has used HFACS as a complement to pre-existing systems within civil aviation in order to benefit from gains made by the military (Villela, 2011).

It is worth mentioning that the primary goal of any safety investigators is to prevent an accident from happening again. It was with this view in mind that HFACS was developed (Shappell et al., 2007). According to Jingru Yan and Jonathan Histon (2014), HFACS bridges the gap between theory and practice and provides a framework for identifying and classifying the underlying causes of operational errors in aviation accidents and incidents. Although HFACS was first developed for aviation, it has been applied and evaluated in many other domains, such as road and maritime transportation, mining, and healthcare. As we can see in Figure 5, HFACS categorizes human operation failures into four levels: (1) Organizational Influence, (2) Unsafe Supervision, (3) Preconditions for Unsafe acts, and (4) Unsafe Acts, with 19 subcategories in total. Before we continue our assessment of HFACS, it is worth providing the reader with a brief description of HFACS major components and causal categories.

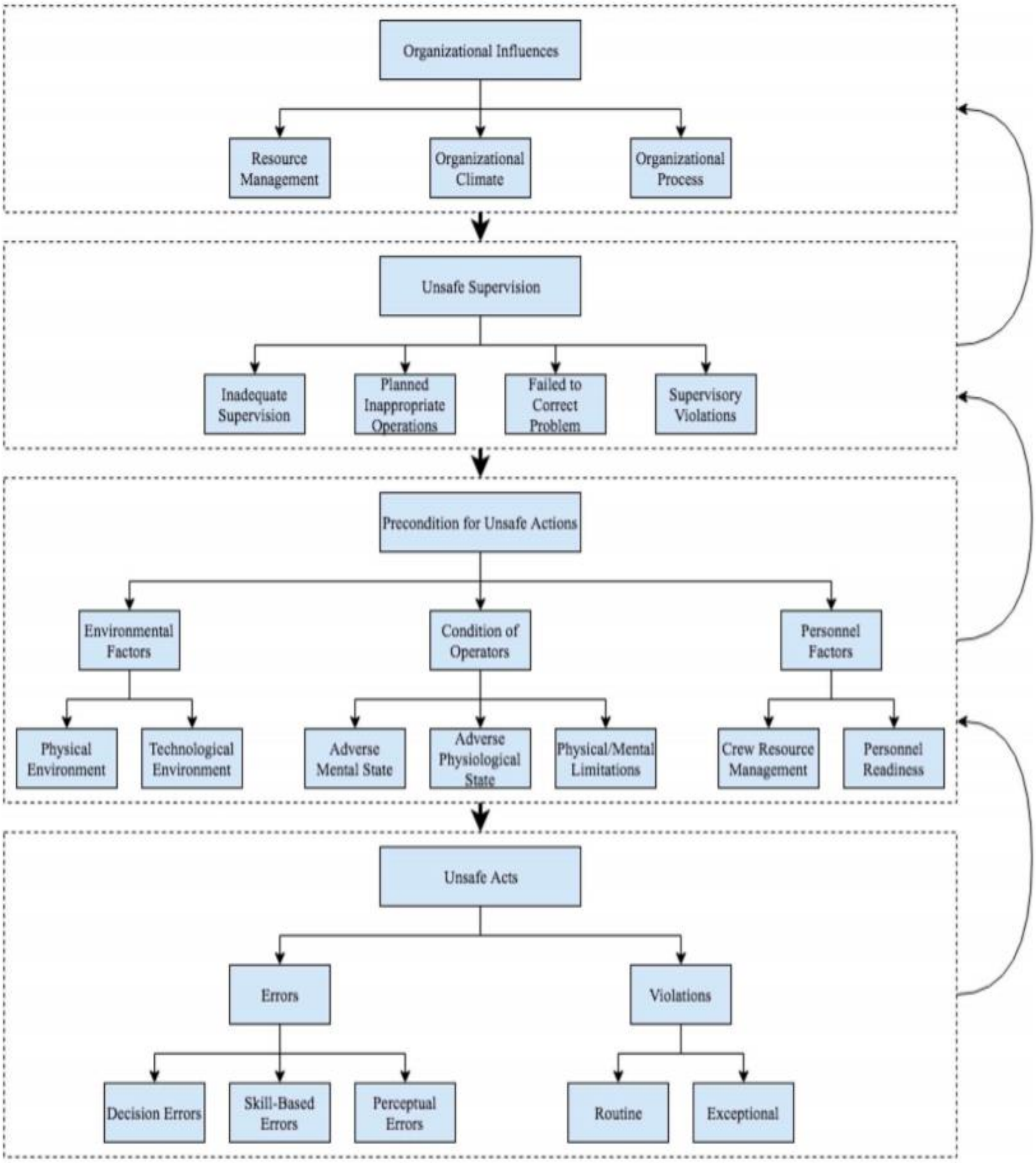

Figure 5. HFACS categories. Note. Adapted from Wiegmann & Shappell (2003).

2.1.3.1 Level A - Organizational Influence

Bad decisions made by top managers of a company can lead to latent defects, directly affecting supervisory practices as well as the conditions and actions of the operators. More often than not, those organizational failures are difficult to be detected by safety experts because they are also within the boundaries of the organization. This level is divided into three factors: the organizational climate, operational process, and resource management (Wiegmann & Shappell, 2003; Villela, 2011).

The organizational climate relates to the current atmosphere/vision within the organization. It includes such aspects as policies, command structure, and culture. Ill-structured organizations with an unsafety culture will witness a drastic increase in their air accident and incident levels. The operational process encompasses the formal process by which the vision of an organization is carried out including operations, procedures, and oversight. In other words, this category refers to corporate decisions and rules that direct the everyday activities within the company. Finally, resource management is how human, financial, and equipment resources necessary to carry out the vision are managed. Inadequate cost-cutting or a lack of funding for proper and safe equipment might unfavorably affect the organization’s performance and safety (Wiegmann & Shappell, 2003; Shappell et al., 2007; Vilella, 2011).

2.1.3.2 Level B - Unsafe Supervision

The James Reason (1990) "Swiss cheese" model of accident causation includes supervisors who influence the condition of pilots and the type of environment in which they operate. Highly influenced by that model, HFACS divides unsafe supervision into four categories: inadequate supervision, planned inappropriate operations, failure to correct a known problem, and supervisory violations (Wiegmann & Shappell, 2003).

Inadequate supervision concerns the oversight and management of personnel and resources, including training, professional guidance, and operational leadership. In fact, the supervisor’s role is to provide an adequate condition for the job to be done safely and efficiently. Many violations that occur in the cockpit have their roots in the lack of guidance and oversight. Thus, it is vital that any meticulous investigation of accident causal factors consider the role of supervision in the origins of human error (Wiegmann & Shappell, 2003; Shappell et al., 2007).

The second category, planned inappropriate operations, refers to management and assignment of work, including aspects of risk management, crew pairing, to name a few. Occasionally, the operational tempo or the scheduling of aircrew is such that individuals are put at unacceptable risk, crew’s rest is insufficient, and consequently, performance is adversely affected (Wiegmann & Shappell, 2003; Shappell et al., 2007).

Failed to correct known problems call attention to those situations in which deficiencies among individuals, equipment, training, or other related safety areas are “known” to the supervisor and still are allowed to continue the way they are. The omission to rectify a well-known issue within the company indeed generates an alarming atmosphere, profoundly influencing the occurrence of unsafe acts (Wiegmann & Shappell, 2003; Shappell et al., 2007).

Finally, the HFACS supervisory violations factor is related to the intentional disregard for existing rules, regulations, instructions, or standard operating procedures (SOP) by managers during their activities. Allowing a pilot to fly without the proper qualification and failing to keep adequate records are examples of supervisory violations. Although they are not common, supervisory violations invariably set the stage for catastrophic mishaps (Wiegmann & Shappell, 2003; Shappell et al., 2007; Vilella, 2011).

2.1.3.3 Level C - Preconditions for Unsafe Acts

As mentioned in section 1.1, approximately 80% of all aviation accidents can be attributed to unsafe acts of aircrew. However, merely honing in on unsafe acts is the same as focusing on the symptoms instead of the underlying causes of the illness. That is why accident investigators should follow more in-depth the reasons that led to unsafe acts in the first place. The process involves analyzing the preconditions of unsafe acts, which includes the condition of the operators, environmental, and personnel factors. HFACS also divided that level into three major groups: environmental factors, the condition of the operator, and personnel factors (Wiegmann & Shappell, 2003; Shappell et al., 2007).

2.1.3.3.1 - Environmental Factors

This precondition for unsafe acts relates to environmental factors that may contribute to unsafe acts. It is also classified into other two factors. The first one is the technological environment, which encompasses a variety of issues, including the design of equipment and controls, display/interface characteristics, checklist layouts, task factors, and automation. The second one is the physical environment, which includes both the operational setting, such as weather, altitude, and terrain, and the ambient environment, such as heat, vibration, and lighting (Wiegmann & Shappell, 2003; Shappell et al., 2007).

2.1.3.3.2 Condition of the Operator

It is fair to say that the conditions of an individual directly influence her performance on her tasks. This category is divided into three HFACS factors. Adverse mental states account for acute psychological or mental conditions that negatively affect performance, such as mental fatigue, pernicious attitudes, and misplaced motivation. The second factor under this category is the adverse physiological states. This factor refers to acute medical or physiological conditions that preclude safe operations, such as illness, intoxication, and the myriad pharmacological and medical abnormalities known to affect performance. Physical/mental limitations encompass permanent physical/mental disabilities that may adversely impact performance, such as poor vision, lack of physical strength, mental aptitude, general knowledge, and a variety of other chronic mental illnesses (Wiegmann & Shappell, 2003; Shappell et al., 2007).

2.1.3.3.3 Personnel Factors

This category of precondition for unsafe acts accounts for the things that an operator can do to create these preconditions. Wiegmann and Shappell (2003) divided this category into two factors. Crew resource management includes a range of communication, coordination, and teamwork issues that impact performance. As to personal readiness, it is related to off-duty activities required to perform optimally on the job, such as adhering to crew rest requirements, alcohol restrictions, and other off-duty mandates. Violations of crew rest requirements and self-medication are examples of this HFACS factor.

2.1.3.4 Level D - Unsafe Acts

Similar to the Reason’s model, Wiegmann and Shappell (2003) classified the unsafe acts of operators into two categories: errors and violations. This level is the most closely tied to the mishap.

2.1.3.4.1 Errors

Errors represent the mental or physical activities of the operators that fail to achieve the intended outcome. Needless to say, given the fact that humans, by nature, make errors, these unsafe acts are the most common acts identified in accident investigations. This category of unsafe acts can be divided into three different HFACS factors (Wiegmann & Shappell, 2003; Shappell et al., 2007).

The first factor classified under this category is decision errors. These “thinking” errors represent conscious, goal-intended behavior that proceeds as designed, yet the plan proves inadequate or inappropriate for the situation. These errors typically manifest as poorly executed procedures, improper choices, or simply the misinterpretation or misuse of relevant information (Wiegmann & Shappell, 2003; Shappell et al., 2007).

Skill-based errors are highly practiced behavior that occurs with little or no conscious thought. These "doing" errors frequently appear as a breakdown in visual scan patterns, inadvertent activation or deactivation of switches, forgotten intentions, and omitted items in checklists. We can also include in this category the manner or technique a person employs when performing a certain task (Wiegmann & Shappell, 2003; Shappell et al., 2007).

The third factor is the perceptual errors. These errors occur when sensory input is degraded, as is often the case when flying at night, in poor weather, or in visually impoverished environments. When faced with acting on imperfect or incomplete information, aircrew runs the risk of misjudging distances, altitude, and descent rates, as well as of responding incorrectly to a variety of visual or vestibular illusions (Wiegmann & Shappell, 2003; Shappell et al., 2007).

2.1.3.4.2 Violations

Whereas errors occur within the rules and regulations of the organization, violations represent a willful disregard for those same rules and regulations that govern safe flight. This category of unsafe acts is divided into two HFACS factors. The first HAFSC factor is routine violations. These violations are often referred to as “bending the rules” and tend to be habitual by nature. They are often enabled by a system of supervision and management that tolerates such departures from the rules. The other type of violation is the one that covers exceptional violations. They represent isolated departures from authority, neither typical of the individual nor condoned by management (Wiegmann & Shappell, 2003; Shappell et al., 2007; Vilella, 2011).

2.1.3.5 Analysis

As previously cited, HFACS is a generic human error-coding framework that was originally developed for US naval aviation as a tool for the analysis of the human factor aspects of accidents. While Reason's model was extremely influential in the way that human errors were viewed in aviation accidents, his model did not suggest remedial solutions. Based upon Reason's model, Wiegmann and Shappell (2003) developed the HFACS to service such a need. Currently, it is the most widely used human factors accident analysis framework. As an example of HFACS recognition worldwide, it has been used in the process for the prospective assessment of the effectiveness of aviation safety products developed as part of the National Aeronautics and Space Administration (NASA) Aviation Safety Program. (Harris & Li, 2011).

Another limitation of the HFACS framework is that it does not provide a suitable mechanism to describe how failures in one organization may affect another organization. This aspect is essential to understand accident processes in open systems, such as the air transport system. (Harris & Li, 2011).

However, the use of HFACS to investigate accidents and incidents involving human error ensured that all levels of the system were considered during data collection and analysis phases of the investigation. The framework allows safety experts to conduct systematic and thorough accident investigations. It can also be adapted to different industries besides aviation, such as railroad (Reinach & Viale, 2006).

Despite its limitations, the HFACS system has been extended and adapted to analyze the underlying human factors causes in accidents involving remotely piloted aircraft and as a basis for the analysis of general aviation accident data by insurance companies. The method has also been developed to investigate maintenance error, and a further adaptation of the system has been developed for the investigation of railroad accidents (Harris & LI, 2011).

2.2 Offshore Helicopter Operations: An Overview

The goal of this section is to compare the Brazilian offshore aviation sector to other countries that are globally recognized as benchmarks in order to give the reader a comprehensive overview of the helicopter operations, risks, and the human factors involved in the sector. Drawing a parallel between the Brazilian offshore operation reality and international data helps us understand how human factors have contributed to offshore helicopter accidents and incidents.

There are specific countries where the characteristics of the offshore sector are very similar to what we have here in Brazil, especially in terms of the scale of operations and geographic conditions. According to the Brazilian National Petroleum Agency (ANP) (2018), the risk analysis of offshore activities in Brazil is done by comparing it with the data from the United Kingdom, the United States, and Norway, countries of reference, and with comparable levels of offshore activity.

In those countries, offshore helicopter companies employ similar aircraft, regarding both models and quantity, comprised of a mix of medium and heavy twin-engine airframe types. Since the beginning of the last decade, mostly heavy and medium twin-engine helicopters have been used for commercial air transport in those countries because generally, they have sufficient range or payload to meet contemporary offshore commercial requirements (Ian, 2016; Norwegian Petroleum Safety Authority, 2017; Oil & Gas UK 2018).

The assessment of the offshore aviation sector in those countries will give us some essential insights into the potential negative impacts of human factors on the behavior of air companies' pilots and the challenges they face to mitigate those risks in their offshore operations.

2.2.1 The Challenges in Offshore Helicopter Operations

Before we dig into operations within those countries, let's take a look at the specificities of the offshore helicopter flights. First, we should bear in mind that helicopter travel offshore is, in many respects, a unique operation because flights are toward remote oil platforms and ships, and most of the time, they take place over the water. Moreover, the fact that it is not rare that the final geographic position of the offshore destination varies adds even more complexity to the operation. Also, aircrew and passengers are equipped with survival suits and other aids for their journey and undergo survival training, which may have an impact on their perception of safety (Oil & Gas UK, 2011).

Another aspect we should mention is that fixed-wing airline operations are not truly comparable with transport helicopter operations because there are distinct differences between the operating regimes for fixed-wing and rotary-wing aircraft. In fact, helicopters conduct operations that fixed-wing aircraft cannot. And offshore helicopter activities are also particularly riskier than onshore transport helicopter activities due to the types of operation,

types, and size of helicopters, operating environment. That is why aircrew and passengers are exposed to entirely different hazards (Oil & Gas UK, 2011).
With all those concerns in mind, during the 1990s, the industry stakeholders promoted several important safety initiatives and conducted much research into improving offshore helicopter safety concerning both the adoption of innovative technologies and the implementation of new safety procedures. Those initiatives were instrumental in achieving significant improvements regarding flight safety, which has contributed to the offshore industry to thrive (Oil & Gas UK, 2011).

2.2.2 Operations in the United Kingdom

According to Oil and Gas UK (2018), helicopters are a critical factor in the operation of the United Kingdom continental shelf (UKCS), a primary industrial sector for the country. Helicopters are intrinsic to offshore operations and particularly in the UK, and there are no realistic alternatives for the UK offshore oil and gas sector as a whole. Those commercial air transport operations take place in a particularly hostile environment. Weather conditions and the distances involved add more risks to offshore operations.
At the end of 2017, the active UKCS helicopter fleet was composed of 70 medium and heavy twin-engine aircraft types (mostly Leonardo AW139 and Sikorsky S92). Over 820,158 passengers were flown offshore in 2017 (an increase of almost 15% compared with the previous year), totaling nearly 69,005 flight hours (a reduction of 22% from 2016).
There have been four fatal accidents (38 casualties in total) and 16 non-fatal accidents since 1997. Two of the fatal accidents were caused by catastrophic component failures and the two others due to human factors. The causes of non-fatal accidents include major component failures, pilot error, lighting strikes, major airframe damage, and main and tail rotor damage. The current five-year average all accident rate per flight hours is 0.52 per 100.000 (it was 0.95 in 2016). As we can see in Figure 6, the five-year average accident for fatal accidents has remained between 0.2 and 0.5 per 100,000 flying hours over the last ten years (Oil & Gas UK, 2018).

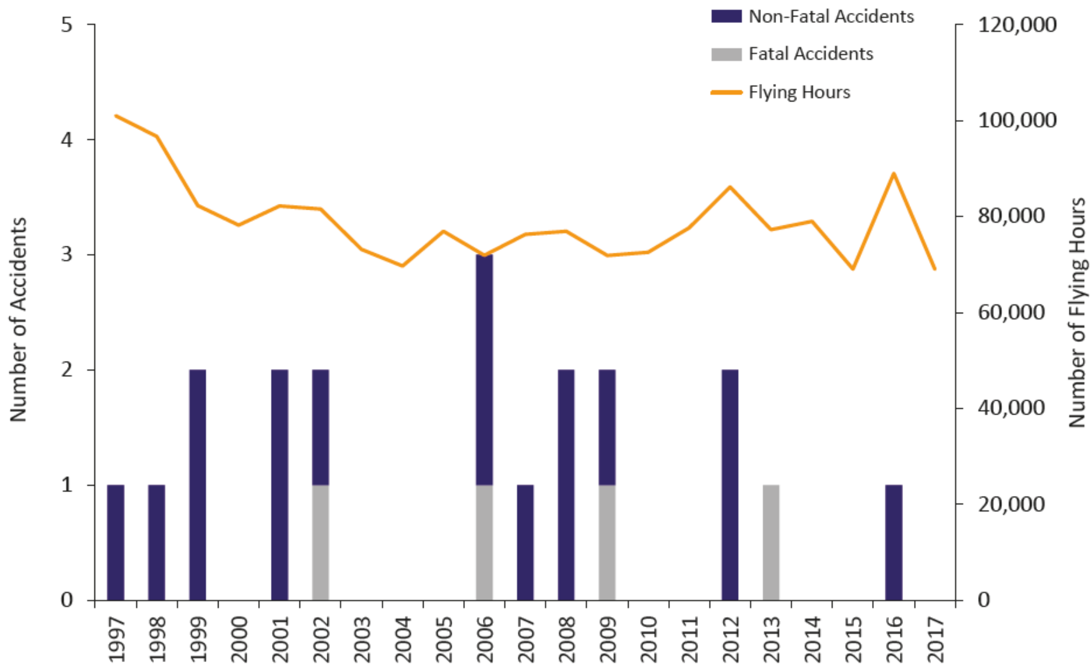

Figure 6. Accident distribution 1997-2016. Note. Adapted from Oil & Gas UK 2018.

It is worth mentioning that operational causes (flight and ground) accounted for 35 percent of accidents, 40 percent were due to technical failures, and 25 percent caused by external factors. The external factor accidents resulted from weather-related events. Finally, the human error was responsible for all operational accidents that occurred in flight (Figure 7).

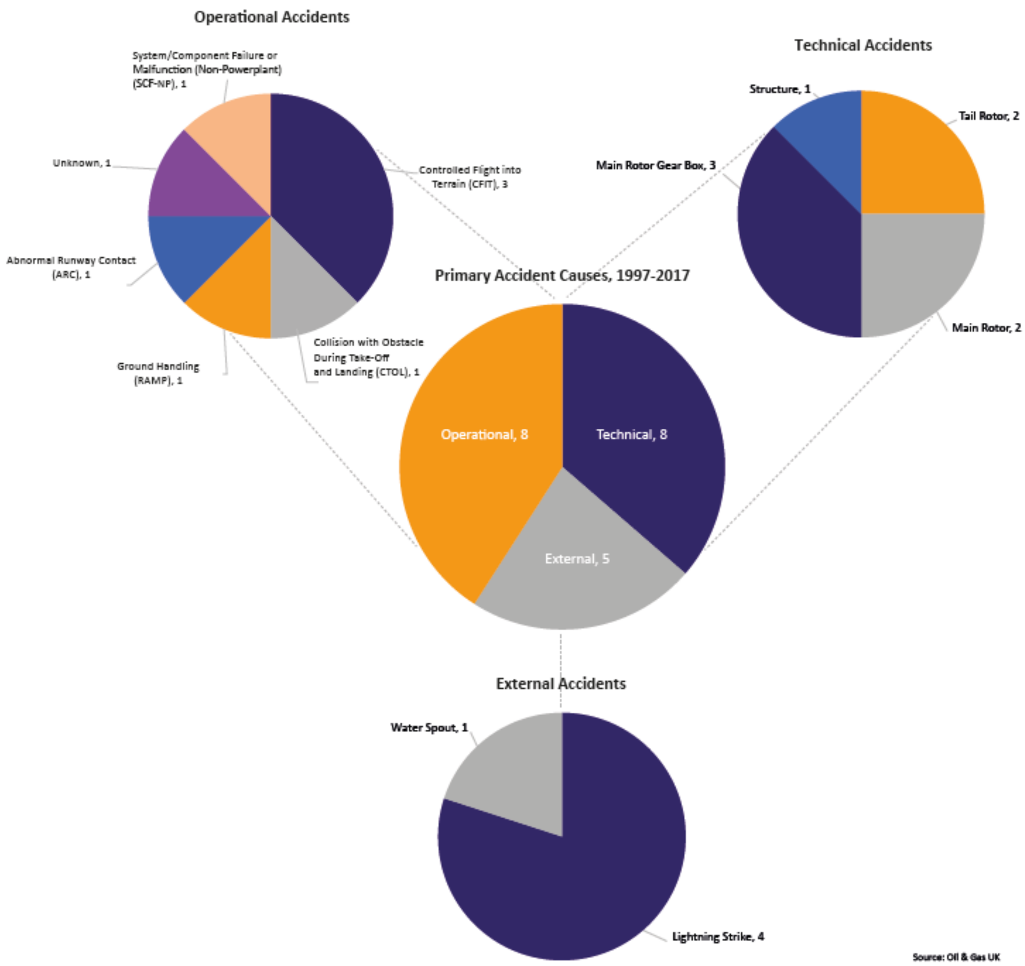

Figure 7. Accident causes 1997-2017. Note. Adapted from Oil & Gas UK 2018.

From the UK Offshore Commercial Air Transport Helicopter Safety Record (1981 – 2010) we gather that in 50% of the fatal helicopter accidents in UK offshore helicopter operations from 1981 to 2010 human factors were the primary cause and the other 50% was related to system or component failures (Figure 8). Concerning non-fatal accidents, according to the same report, 17% was mainly caused by human factors, 17% by defective maintenance, 27% by external influences (weather, helideck turbulence, etc.), and 39% by system or component failures.

In the decade 1991 to 2000, weather-related occurrences dominate the numbers. Nonetheless, reduced maintenance and human factor occurrences declined during that period. This might be the result of introducing some new helicopter types and several safety initiatives on the North Sea along with harvesting the benefits from two pilot operations and crew resource management (CRM) training introduced in the previous years (Oil & Gas UK, 2011). The concept of CRM will be discussed in section 2.3.2.4.

	Primary Cause	81 - 90	91 - 00	01 - 10	81 - 10
People / Machine	Component / System – Failure / Defect	13	2	1	16
	Human Factors	3	1	3	7
	Loss of Control	0	0	0	0
	Defective Maintenance	6	1	0	7
Total		**22**	**4**	**4**	**30**
External Influences	Weather	0	3	2	5
	Helideck Turbulence / Exhaust Plumes	2	1	0	3
	Excess Vessel Motions	1	0	1	2
	Other Causes	1	0	0	1
Total		**4**	**4**	**3**	**11**
All Causes		26	8	7	41

Figure 8. Accident causes 1981-2010. Note. Adapted from Oil & Gas UK 2011.

During the years 2001 to 2010, there has been a marginal increase in human factor occurrences. The introduction of new monitoring systems in the mid-1990s and its use across the UK offshore fleet has made a significant contribution toward monitoring the condition of critical components and ensuring their timely removal before failure. The continuing high-quality crew training and the introduction of an innovative operation monitoring program across the UK offshore fleet has paid off in controlling the number of human factor events that might ultimately lead to a reportable occurrence. External influences have been the cause of the most significant occurrences, and most of these have been weather-related (Oil & Gas UK, 2011).

The data from the investigation of those tragic accidents highlight the fact that human factors still are a significant contributing factor to accidents to occur. Offshore helicopters operate in a hostile environment, and because of that, continuous improvement to minimize and eliminate the risks is paramount. Additionally, non-fatal reportable accidents on the UKCS have been progressively reduced over the last 30 years but continue to happen. This situation shows the necessity for the UK oil and gas industry to continue to pursue current and future safety initiatives and research projects to further mitigate risks (Oil & Gas UK, 2011).

2.2.3 Operations in Norway

Operational conditions in Norway are quite similar to those in the UK; in other words, helicopter pilots also fly in a hostile environment. At the end of 2017, the active helicopter fleet was composed of 52 medium and heavy twin-engine aircraft types (mostly Sikorsky S92). Over 690,000 passengers were flown offshore in 2017, totaling nearly 38,000 flight hours (Norwegian Petroleum Safety Authority, 2017).

The offshore industry in Norway has experienced substantial changes, and the prospects are quite uncertain. A reduction in the business may result in increased pressure on safety through downsizing and a strong focus on the costs, both within the oil companies and the helicopter operators. Norwegian safety experts are concerned about the negative impact of economics on the level of safety, which may lead to the reduction of safety margins over time. The prospect of new areas of exploration at the Barents Sea may introduce new and potentially more significant challenges for offshore transport by helicopter due to long flying distances and a hostile environment (Krakenes et al., 2017).

The incidents in offshore aviation operations at the North Sea also present associated human factors. In Figure 9, we can see the correlation between human factors and helideck incidents from 2008 to 2017. In this period, over 50% of the helideck incidents were caused by human factors, mainly violations of procedures and wrong or missing information (Norwegian Petroleum Safety Authority, 2017).

In the period between 1999 and 2017, the Norwegians suffered one fatal accident, which gives a rate of 1.0 fatality per million-person flight hours. As to the UK sector, in the same period, the rate is 4.0 fatalities per million-person flight hours. According to Norwegian authorities (2015), among potential threats to helicopter safety are the reduced competence among technicians and pilots in the helicopter companies due to the retirement of existing personnel and the lack of skill and resources regarding offshore helicopters in the Civil Aviation Authority (Norwegian Petroleum Safety Authority, 2017).

According to a comprehensive study about helicopter safety focusing on the period 2010-2015, conducted by a Norwegian independent research organization called SINTEF, two out of six most significant potential threats to helicopter safety in the coming period are related to human factors – reduced competence among technicians and pilots and lack of expertise and resources regarding offshore helicopters in the Civil Aviation Authority (Krakenes et al., 2017).

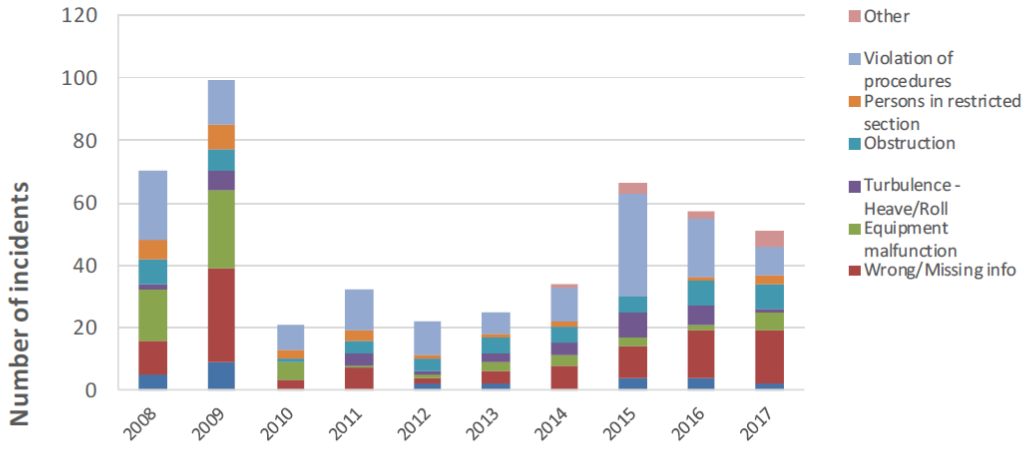

Figure 9. Helideck factors 2008-2017. Note. Adapted from Norwegian Petroleum Safety Authority (2017).

2.2.4 Operations in Brazil and the New Law of the Aeronaut

In Brazil, the offshore helicopter fleet is composed of around 70 medium and heavy twin-engine aircraft types (mostly Leonardo AW139 and Sikorsky S92). In 2017, Macaé airport, the main airport that gives support to the offshore industry, was ranked in 17º position considering aircraft operations (1.8% national total). It also had 27,695 landings and take-offs, and over 179,888 passengers were flown to the oil rigs (Infraero, 2017).

Flying helicopters in the personal transportation service for the offshore oil and gas exploration and production operations in Brazil is also a demanding activity because of the features of operational area (offshore platforms are located off the cost - 50 miles on average), the aircrew workload demands and the cost pressures (Gomes et al., 2015).

In their in-depth study, Gomes et al. (2015) analyzed the factors presented in pilots' activities that may, in some way, compromise or enhance their performance, the constraints and affordances which they are subject to, and where possible the links to their associated risk factors. That assessment was conducted in the Campos basin, the most important petroleum basin in the country, by researching pilots' daily routine. After a comprehensive field study, the researchers concluded that some human factors should be addressed so as to improve the system's safety. Resource management (budget constrains in operation), crew resource management (pilot and copilot relationship), inappropriately planned operation (flight schedules), and operational process (inadequate flight area map) were pointed out as relevant causes of pilots' big concerns.

According to Brazilian Center for Investigation and Prevention of Aviation Accidents (CENIPA), the most frequent contributing factors identified in helicopter accident investigations that occurred between 2008 and 2017 were directly related to human factors (pilot judgment, flight planning, and management supervision, among others), which represent more than 55% of the total contributing factors of helicopter accidents (Figure 10) (Brasil, 2018).

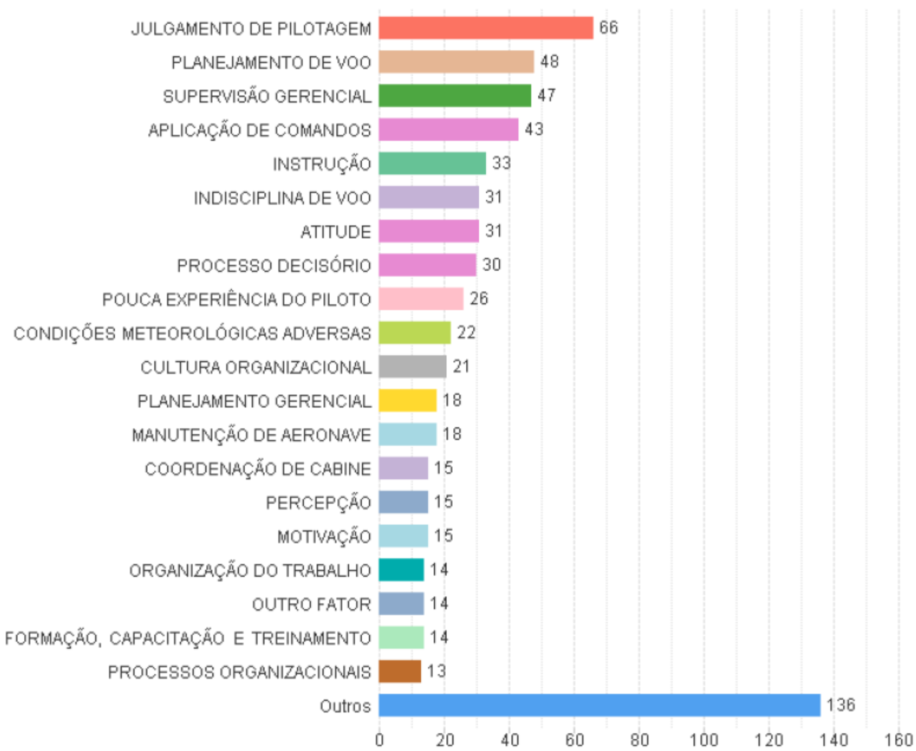

Figure 10. Contributing factors of 121 helicopter accidents in Brazil 2008-2017. Note. Adapted from Brasil (2018).

When it comes to severe incidents (Figure 11), the situation is very similar. The most frequent contributing factors identified in helicopter accident investigations that occurred in the same period were also related to human factors (management supervision, pilot judgment and flight planning, among others), which represent more than 50% of the total contributing factors of rotary-wing aircraft incidents (Brasil, 2018).

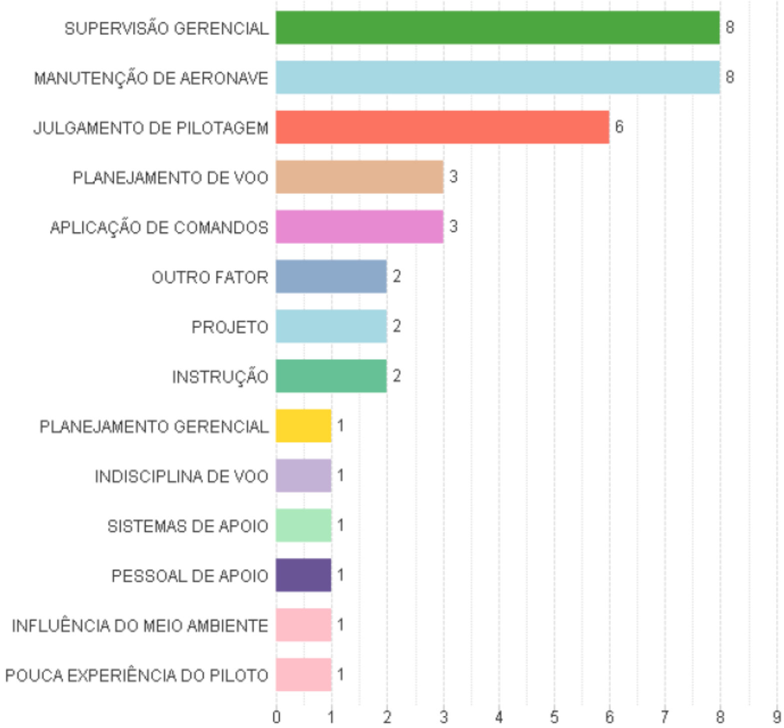

Figure 11. Contributing factors of 20 serious helicopter incidents in Brazil 2008-2017. Note. Adapted from Brasil (2018).

The implementation of the new law about the exercise of the profession of aircrew, also called the law of the aeronaut, has brought new safety patterns to the aviation industry so as to mitigate the risk of aircrew and technical staff fatigue. Concerning the changes, there are two main points to highlight. The first one is related to time offs and working day limits for aircrew and mechanics. The objective is to reduce the duty period and give more time for the personnel to rest between their flight activities. Nonetheless, the operational limitations established in this Law may be modified by the ANAC based on the Human Fatigue Risk Management System.

This system is intended to reduce crew fatigue and, consequently, the occurrence of aeronautical accidents and incidents that have fatigue as a contributing factor. It should be implemented and monitored by the union of the category, association of companies, and government agencies (Brasil, 2017). When implemented, that fatigue control system will contribute to improving safety aviation by mitigating one of the most relevant human factors in the offshore aviation sector.

The oil & gas industry in Brazil has been profoundly affected by the outcomes of the Operation Car Wash – a huge anti-corruption investigation. That operation brought to light the shady relationship between government contractors and high-profile politicians. The state-owned oil and gas company was part of a system of institutionalized corruption whereby corporate executives overpaid for contracts that were awarded based on their political ties. After the investigation, the national oil and gas company restructured its governance and compliance sectors. However, the sector still faces enormous challenges when it comes to rebuild its reputation and to attract domestic and international investments. Before investing in Brazil, foreign companies still consider the pros and cons of its huge market against the existence of widespread malpractice. It is still unclear if those anti-corruption efforts will bear fruit by improving the transparency and efficiency of the country's business environment (Monteiro & Albuquerque, 2018).

2.3 Human Factors

As discussed in section 1, human factors in aviation represent a comprehensive multidisciplinary approach that uses the principles and methods of social and behavioral psychology, social sciences, engineering, and physiology in order to improve human performance, reducing their error in interaction with the aircraft. This perspective is based on the premise of individuals synergistically working in teams and operating the safest way as possible. This concept adds the principles of ergonomics and teamwork to the safety of flight operations. In spite of all those efforts, human error is still a threat to the survival of the organization, which leads safety professionals to continually seek to mitigate them in an efficient way, whereas keeping the company financially viable (Villas Boas, 2014).

Among all human factors, some of them are more relevant to the aviation industry as a whole and particularly to helicopter offshore operations than others. The assessment of HFACS and the unique characteristics of helicopter flights in the offshore environment leads us to hone in on specific human factors that are consistently mentioned in the literature as those with more impact on that kind of operation, such as organizational culture, communication, crew resources management, decision making, leadership, motivation, safety behavior, stress, fatigue, and human error. In this section, we will discuss in more detail those human factors and their influence on pilots' safety behavior within the offshore industry.

According to Appelbaum & Fewster (2004), the success of some air companies' safety management is due, among other operational reasons, to their efforts to dig into the organization's overall culture, ethics, values, and vision. Those practices that engender safety

— sufficient staffing, appropriate skill sets, clear communications, effective teamwork, sense of community, a clear mission, vision, procedures and policies, strong leadership, and sufficient resource allocation — also foster employees' commitment, overall organizational efficiency, and customers' satisfaction. It is fair to say that the understanding of the impact of those human factors on the organization will pave the way towards safety and proficiency in the long run. That is why the organization's senior administrators must champion those safety objectives and provide the resources needed to operationalize the company's vision and mission and must also be responsive to the insights and recommendations of their personnel.

2.3.1 Organizational Culture and Influence

As mentioned in section 1.1, since the late 1990s, top safety experts have dramatically increased their attention to the organizational aspects of the aviation industry. More specifically, safety studies have focused on the impact of corporate policies, processes, and practices on the creation of latent failures and behavioral norms that ultimately influence safety behavior. Therefore, there has been an increased emphasis on the study of companies' culture, in particular on the safety aspects of the culture, so as to mitigate the contribution of organizational influences to aviation mishaps (Salas & Marino, 2010).

As a vital component of the organizational culture, the concept of safety culture first appeared in the accident investigation report on the 1986 Chernobyl nuclear disaster. The errors and violations of the standard operating procedures that contributed to the accident were seen by investigators as being evidence of a poor safety culture at the nuclear plant (Salas & Marino, 2010). Other renowned accident investigations outside the realm of aviation, such as Three Mile Island (Pennsylvania, US, 1979), The Herald of Free Enterprise (off Zeebrugge, Netherlands, 1987) and Piper Alpha (North Sea, 1988), have also moved the concentration of the analysis into the system as a whole. Those episodes, extensively discussed in the literature, all illustrate the movement towards an organizational view of complex events (Griffin et al., 2015).

From those accidents, many safety specialists within different industries, such as health care, nuclear power, and construction, have been painstakingly trying to assess and improve their organizations' safety culture. Likewise, in order to reach a high level of safety, air companies' top managers have also been learning from accidents outside their field of expertise and therefore addressing organizational influences to aviation mishaps (Salas & Marino, 2010). Needless to say, that initiative also has a positive managerial impact on the organization. The overwhelming consensus in the literature is that more than any other organization characteristic, the organization's culture is the key to a competitive advantage in the market. A company with a healthy and robust culture is much more prepared to overcome the operational and economic challenges imposed by the aviation industry (Appelbaum & Fewster, 2004).

The sociologist Ron Westrum has categorized organizational cultures according to the way they deal with safety-related information. He identified three types of culture - pathological, bureaucratic, and generative (Figure 12). Organizations conducting potentially hazardous operations, such as aviation and nuclear power, need a diversity of thinking in order to anticipate the variety of possible failure scenarios. The absence of this requisite imagination can potentially contribute to the developmental stages of an organizational accident (Reason, 1997).

Pathological culture	Bureaucratic culture	Generative culture
• Don't want to know.	• May not find out.	• Actively seek it.
• Messengers (whistle-blowers) are 'shot'.	• Messengers are listened to if they arrive.	• Messengers are trained and rewarded
• Responsibility is shirked.	• Responsibility is compartmental-ized.	• Responsibility is shared.
• Failure is punished or concealed.	• Failures lead to local repairs.	• Failures lead to far-reaching reforms.
• New ideas are actively discouraged.	• New ideas often present problems.	• New ideas are welcomed.

Figure 12. How different organizational cultures handle safety information. Note. Adapted from Reason, 1997.

The growing interest in understanding the current state of safety culture is closely associated with the need to transform the culture into a more desirable state. Managers want to know the current state of safety culture in their organization and how they can improve it (Salas & Marino, 2010). Thus, the safety culture of an airline company is initially transformed by its managers and then spreads across the entire organization with the main impacts on the operational area (Anca et al., 2010). If this process is not properly structured, safety programs and technical qualifications can only meet the requirements of the local civil aviation agency rather than effectively promote significant changes to operational safety. Therefore, the role of the leaders of the organization in the conduct of this process is paramount (Villas Boas, 2014).

According to Salas & Maurino, two fundamental aspects of safety culture should be assessed: components and dynamics. Components refer to constituent parts that collectively describe safety culture. These parts of safety culture can be divided into four categories in the form of a pyramid (Figure 13). At the base of the pyramid are the foundational safety values, next are the organizational factors (safety leadership strategies), followed by the attitudes and opinions (safety climate), and at the top of the pyramid are safety behaviors (or safety performance). The second aspect of the safety culture is dynamics, which refers to the interaction between the constituent parts that yields a dominant cultural state.

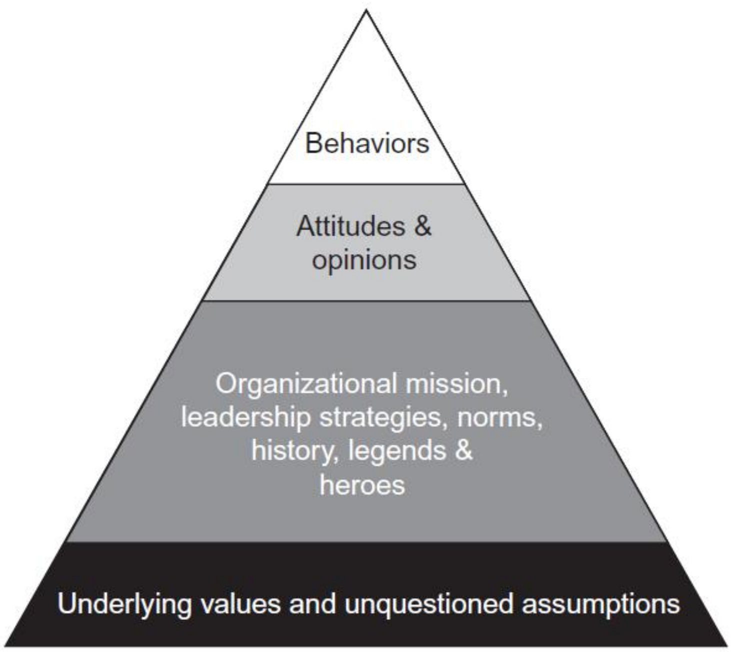

Figure 13. Safety Culture Pyramid. Note. Adapted from Salas & Maurino, 2010.

In high-consequence industries such as aviation, health care, nuclear power, and chemical manufacturing, the safety of the employee and the system has to be an enduring value within the organization. Hence, the organization’s business plan and daily practice have to take into account all those safety issues. Organizational mission, policies, procedures, employee evaluation tools, reward, and penalty systems, and leadership practices integrate the organizational factors. The personal values of corporate leaders usually tend to become enduring values of the organization, which are then translated into strategies that will sharp the safety culture. Employees' attitudes and opinions are the primary indicators of the organizational safety climate. In other words, safety attitudes offer a brief observation of employee perceptions, reactions, and opinions about safety policies, procedures, practices, and leadership. Attitudinal measures assess individual and group-level perceptions of the overall safety of the organization. Finally, safety performance is the collective outcome of observable safety behaviors such as successful error recoveries, systemic safety improvements in response to error or hazard reports, and errors resulting in incidents or accidents (Salas & Marino, 2010).

Appelbaum & Fewster (2004) also call our attention to another crucial aspect of the aviation environment related to organizational culture — diversity. The aviation industry is characterized by international and complex relationships among its members. The human factors approach views diversity as a variance in national, linguistic, and professional cultures (managers, pilots, air traffic controllers, flight attendants, and maintenance technicians) that may have a negative consequence on communications and safety. The differences in language, origin, and professional cultures pose well-documented challenges to operational personnel. Nonetheless, some proactive airline companies, such as Continental Airlines and Delta Airlines, are realizing the benefits of respecting the diversity of domestic and international populations and are strategically matching population demographics to their human resource management practices. Those companies have demonstrated that diversity can be an important source of proficiency and creativity.

Of course, unhealthy organizations still pose a threat to aviation personnel, travelers, and the general public. That is why the ICAO has championed the practice of investigating major catastrophes from a human factor organizational perspective for more than twenty-five years now. ICAO’s 1993 Human Digest circular titled, Human Factors, Management, and Organization, was rich in accounts of accidents in which the complex and deadly consequences of organizational deficiencies were cogently highlighted. The mechanisms of individual human error have been better understood since then, and adequate defenses to cope with their damaging consequences are already in place. Hence, the natural next step to improve aviation safety is now to turn attention to management and organizational processes. (Appelbaum & Fewster, 2004).

Separations between national, linguistic, and professional subcultures may also give rise to serious communication problems (an issue that will be addressed in the next section). Research results revealed big cross-cultural differences in command interactions and tolerance for rules, routines, and set procedures in airline companies. Due to the inherently global nature of the airline industry, companies' top managers have to pay close attention to and wisely deal with organizational aspects, such as power distance, collectivism, individualism and uncertainty avoidance. (Appelbaum & Fewster, 2004).

Furthermore, institutional arrangements that favor coordinated collective actions, whereas diluting individual competition, can implement a high degree of operational safety in an organization. With clear, precise, and impersonal rules, it is possible to increase productivity and cooperation among all sectors in an airline company, as well as to strengthen a collective vision in which operational safety can become an unmeasurable institutional value (Villas Boas, 2014).

Successful air companies, such as Duncan Aviation, Southwest Airlines, and Delta Airlines, have paid a great deal of attention to organizational culture. Those companies plan and continuously develop a safety and customer-centric culture by creating a respectful, learning-oriented, and agile workforce, with a sense of community, and the ability to respond quickly and to customer needs and change. Within those organizations, employees are participative, empowered, committed, and motivated, which leads the organization to be much more aware of customer perceived value and customer perceived risk (Appelbaum & Fewster, 2004).

2.3.2 Communication and Crew Resources Management

The most tragic crash in aviation history so far happened in 1977 when two Boeing 747 airliners collided on the runway of Los Rodeos Airport on the Spanish island of Tenerife. This terrible accident caused the deaths of 583 people. The number of fatalities provoked by airplane-related crashes was exceeded only by the terrorist attacks on September 11, 2001. The investigation report indicated that one of the factors contributing to the Tenerife air accident was the use of nonstandard phrases in communications between one of the pilots and the flight engineer (Salas & Maurino, 2010).

Wiegmann and Shappell (2001) found out during their research that approximately 30 percent of commercial flight accidents were strongly correlated with crew resource mismanagement. Another comprehensive study conducted by Lufthansa in the late 1990s pointed out that 53 percent of all incidents revealed communication problems (Ebermann & Scheiderer, 2013). Sexton's and Helmreich's research showed that communication had been implicated in 80% of all accidents from 1980 to 2000 (Salas & Maurino, 2010). What's more, poor communication between pilots and controllers with the consequent potential safety risk is the most frequently cited item by NASA in its Aviation Safety Reporting System (Villas Boas, 2014).

2.3.2.1 Situational Awareness

According to Endsley, one of the most relevant concepts in aviation is called situational awareness, which can be defined as the capacity of identifying critical factors in the environment, understanding what those factors signify concerning the aircrew's goals, and being able to understand what will happen in the near future. With a high level of situational awareness, aircrews are able to function timely and effectively (Salas & Maurino, 2010).
Salas & Maurino (2010) argue that communication is vital to building an adequate team situational awareness. That is, team members need to have information that will help each one develops relevant expectations about the team task. Put it differently, planning and leadership help to build team situational awareness by facilitating effective communication. Thus, in the cockpit, crew members need to communicate with each other so as to develop a shared mental model, team situational awareness, and adaptability.
That is why the paramount role of aircrew communication in aviation has long been recognized and intensely studied among safety experts. When crew members face high-risk situations, which is quite common in the aviation environment, communication is even more critical in the timely execution of procedures, shared situation awareness, and effective decision making (Vidulich et al., 2014).
In fact, over the past decades, researchers have pushed the aviation community to develop the Crew Resource Management training to effectively address the need for communication and other forms of crew interactions so as to improve the overall system safety (Vidulich et al., 2014).

2.3.2.2 Speak up

Many air accidents in recent history have demonstrated that crew members' failure to speak up can have devastating consequences. Speak up can be defined as an upward voice-directed from lower to higher status individuals within and across teams, that challenges actions or decisions to prevent or mitigate errors. Those professionals too often choose silence instead of speaking up in situations where they potentially endanger their own lives and other people's. Despite decades of crew training, this problem persists and still poses a high risk to aviation safety (Bienefeld & Grote, 2012).

In several situations, crew members, similarly to professionals in the emergency room of a hospital or the control room of a nuclear power station, are the last line of defense with the potential to preclude the fatal chain of errors in highly ambiguous, stressful, and complex situations (Dekker, 2014). Therefore, the understanding of human information processing is crucial to maximizing the effectiveness and safety of the aviation system as a whole. More often than not, failures in human information processing have contributed to tragic aviation accidents (Salas & Marino, 2010).

According to Bienefeld & Grote, (2012), with hindsight, surviving crew members often report that they had a bad ‘‘gut feeling’’ during the critical moments before the flight accident and that they actually had considered to speak up, but for some reason, they decided to remain silent instead.

In their research, Bienefeld & Grote (2012) tried to understand the reasons that lead crew members not to speak up when a critical situation calls for it. Among copilots, 43 percent feared that speaking up would damage their relationships with captains. They also mentioned feelings of futility (33 percent). As to captains, 53 percent indicated that speaking up about misinterpretation or mistakes could damage their relationships with copilots, and they also wanted to maintain a favorable team climate. As far as many captains are concerned, sometimes it's hard to know when they are a colleague and when they are the boss in the cockpit. In general, crew members reported that they had spoken up in only 50 percent of all latent voice episodes they had experienced in their current job position so far.

The study also indicates that captains, in spite of their high status and authority, were sometimes reluctant to raise safety-relevant concerns or observations to other crew members. This can make us conclude that crew members' willingness to speak up is not as definitely and simply determined by status differences, as is suggested by the existing literature. What's more, the findings also pointed out that surprisingly gender, age, and tenure did not explain any variance in speaking up (Bienefeld & Grote, 2012).

We should bear in mind that another critical factor in promoting speaking up is leadership. Top managers and captains can actively reduce intimidating status barriers and help create a climate of psychological safety – that is, a climate that allows team members to feel safe in interpersonal risk-taking – which in turn also predicts speaking up (Bienefeld & Grote, 2012). This topic will be further discussed in a later section.

2.3.2.3 Written Communication

Dos Santos & Vieira (2010) highlight the importance of written communication in the aviation industry. The level of safety within an airline is strongly correlated with how this company is structured to promote adequate communication flows that support the decision-making process. In reality, poorly conceived and dubious documents, such as operational procedures or safety reports, can drastically compromise aviation safety. In a high-risk industry, such as aviation, written communication should be used as a tool to generate safety and synergy among its members.

Aviation schools should, therefore, promote writing activities that do represent the writing form expected by the aviation community. Students should be trained to write documents that are crucial to their activities proficiently. Communication skills should be incorporated into the flight school curriculum, with well-defined goals in the evaluation process and with clear performance standards. Efficient communicators can contribute to decreasing the possibility of human error (Dos Santos & Vieira, 2010).

Furthermore, in many military aviation contexts, electronic text chat has already become the primary communication mode, with voice communications being used less frequently. It is worth noticing that that trend is occurring in times in which texting on smartphones is a common form of interpersonal communication. Although electronic text chat may provide persistent records that benefit certain types of operations, employing them in time-sensitive applications could pose unnecessary risks to a flight. The challenge ahead is how to wisely balance written and verbal communications in the cockpit in the near future (Vidulich et al., 2014).

2.3.2.4 Crew Resource Management

Dekker (2014) defined CRM as a set of principles that pilots and other crew members employ to make effective use of all available resources – human, equipment, and information. CRM principles address workload management, coordination and communication, leadership and support, situation awareness, and decision-making. The concept of "team" includes but is not limited to flight deck crew members, cabin crew, air traffic controllers, dispatch, maintenance staff, and operations managers. Hence, coordination and communication among team members are essential.

Bienefeld & Grote (2012) considered two insights to better explore possible reasons underlying crew members' silence in critical flight situations. First, crew members were focused on what they perceived as potentially negative outcomes or risks of speaking up. Their desire to avoid those negative outcomes seems to have played a paramount role in their decision to remain silent. Second, there were significant group differences in crewmembers' choice of reasons to explain their silence. Copilots and captains were all concerned that their speaking up could damage relationships and that they would lose other crew members' acceptance and trust.

Bienefeld & Grote (2012) suggest that after years of CRM training highlighting the importance of a positive team climate and equality in the cockpit, some captains may have developed an excessive desire to be perceived as open and permissive, which, in their minds, conflicts with their duties to intervene whenever they observe poor performance or deviations from safety rules. Therefore, CRM training should be redesigned in order to address the potential for such misunderstandings. It should be made clear that an open culture for voicing concerns can and must coexist with good leadership.

The expected inclusion of automation in modern aircraft will demand new communication and coordination skills among crew members. New cockpit automation will ask for new CRM strategies, such as the need for explicit cross-check between the captain and first officer following any input into the autopilot system. As mentioned earlier, communication allows crew members to reflect on thoughts and to construct shared mental models and situational awareness. Moreover, high-performing teams tend to communicate useful information in meaningful ways, whereas automation tends to communicate either raw data or commands rather than intermediate interpretations (Vidulich et al., 2014).

One of the principles of CRM training is that pilots should clearly articulate their concerns and advocate an appropriate course of action. This tenet is usually couched in terms of "assertiveness" and "advocacy." Captains ultimately decide the course of action but are supposed to consider input from subordinates seriously and carefully (Dekker, 2014).

2.3.3 Decision Making and Teamwork

According to the FAA, decision making is the mental process of collecting and assessing all available information in a specific situation, as well as the deliberate evaluation of action alternatives leading to a timely decision as to which course of action to take (Ebermann & Scheiderer, 2013). Pilots make decisions all the time. Those decisions are made between two poles: quick/ intuitive; and coordinated/rational. The more complex a situation appears to be, the more essential it is to use a decision model (Salas & Maurino, 2010; Ebermann & Scheiderer, 2013).

However, most of the decisions are routine and are hardly thought of as "decisions," but rather more like procedures following. Normally, the adequate option to choose is clear, and its consequences are well anticipated that little cognitive effort is involved, as long as the appropriate time to make the decision has been identified. This rule-based behavior typically only fails when the pilot forgets to perform the procedure often in times of high workload. (Salas & Maurino, 2010; Ebermann & Scheiderer, 2013).

The other type of decision is when two or more choice alternatives are plausible in the context, where cues in the environment must be considered to drive the correct option. In this situation, the outcome of one or the other choice cannot be predicted with certainty, and harmful consequences could result from some of the possible outcomes. This risky decision-making falls within the class of knowledge-based behavior (Salas & Maurino, 2010).

The intuitive decision may occur when pilots are subjected to time constraints or find themselves in situations without practical knowledge, and then they resort to their ‘‘gut feelings’’. However, even when intuition emerges collectively, it has yet to be proven just how close it approximates sound arguments. That is why intuition serves exclusively as a supplemental assessment, while success through intuitive action without rationality should be seen as a mere stroke of luck (Ebermann & Scheiderer, 2013).

At the end of the 1970s, the aviation industry began to zero in on issues of leadership, command, and decision making in the cockpit with the purpose of improving safety standards. A decade and a half later, a study conducted by Helmreich et al. demonstrated an empirical correlation between pilot performance and pilot attitudes regarding the effects of fatigue, stress, and team function on their decision-making ability. This study correlated psychometric testing of no personality traits with pilot performance and was the foundational study for subsequent work in aviation and medical safety attitudes measurement (Lyndon, 2006).

The Lufthansa study (already mentioned in section 3.2) also pointed out that 80% of all accidents reveal deficiencies in the leadership of and collaboration between the crew. It also indicated that 70% of all accidents occur following incorrect decisions or a failure to make decisions (Ebermann & Scheiderer, 2013). Moreover, the research conducted by Gautam & Mathur (2018) suggested that the majority of aircraft mishaps are caused by aircrew members' decision making or judgment errors.

That is why once human factors were acknowledged as crucial performance indicators in aviation, safety specialists became interested in issues of situation awareness, communication, shared mental models in decision making, and whether training targeting these issues could improve aircrew safety proficiency (Lyndon, 2006).

Gautam & Mathur (2018) categorize four types of decision-making styles. The first one is vigilance - the decision-maker takes action only after carefully investigating a range of alternatives and evaluating their positive and negative aspects. The second style is buck-passing, which is a version of defensive avoidance. In this situation, the individual avoids making the decision and therefore passes the buck. The third one is called procrastination, which is another form of defensive avoidance. It emphasizes the situation when the individual continuously puts off decision making by engaging in different tasks. The last style is the hyper-vigilance. This defines the instant decisions by the individual to avoid stress and conflict in case of limited time.

It is generally agreed that group decision making is a widely studied research subject in social psychology. In this context, it is interesting to note that a type of decision bias, referred to as preference bias, seems to be closely related to plan continuation error. Preference bias is characterized by persistence in the choice of an initially preferred but inadequate solution to a problem, even though relevant information that could be used to identify an appropriate solution has been exchanged within the group (Bourgeon et al., 2013).

In section 3.2.2, we highlight the critical role "speak up" plays in preventing the fatal chain of errors in highly demanding and risky situations during flights. In fact, in a collaborative problem-solving context, expressing dissent and justifying it with arguments has been demonstrated to improve the quality of decision making by enabling a revision of the mental

representation of the situation and therefore avoiding the negative consequences of preference bias (Bourgeon et al., 2013).
According to Gautam & Mathur (2018), mindfulness and psychological flexibility are paramount to establish sound mental representations that will lead to an improved decision-making process. On the one hand, mindfulness is a positive psychological construct that has a measurable impact on aircrew to make more strategic decisions and avoid information overload.
On the other hand, psychological flexibility can seriously improve decision making and stimulate an aircrew to think outside the box, if you will. Pilots with psychological flexibility can effectively deal with unpredicted and complex situations and can come up with alternative ideas and solutions. With the help of the right tools and methods, it is feasible to provide mindfulness training for the aircrew to enhance their performance. Thus, mindful decision-makers are more likely to learn to make better decisions as they are more open to feedback and less inclined to misread the situation (Gautam & Mathur, 2018).
We also should bear in mind that teamwork is a predominant factor to enable crew members to be aware of the situation as a whole and enhance critical decision-making regarding their course of action. That is why it is essential to understand the factors that influence aviation crew performance in order to be able to replicate successful team outcomes in future situations. Furthermore, assessing coordination, communication, and decision-making can provide a better foundation for training aviation crews (Salas & Maurino, 2010).
An important topic to add to aircrew teamwork training is leadership, more specifically when captains need to respond to situations involving ambiguity. Pilots should be encouraged to respond to uncertainty by seeking additional information and systematically considering alternative interpretations. In cases in which high workload or time limitation prevented this sort of inquiry, pilots should be trained to resort to the synergy of teamwork and select the most conservative response (Dismukes et al., 2007).
Another interesting aspect to be considered in decision making in aviation is ethics. Ned Reese researched the role of ethics in decision making among managers in the aviation industry. He argued that the issues leading to error invariably have an ethical component. Unfortunately, different from the majority of professional sectors that tend to be recognized for a set of guiding principles, the aviation and aerospace industries do not have a code of ethics that would provide a set of principles and a model for ethics and decision making. This

code would contribute to aviation safety by conveying moral values that could prevent omission and complacency (Appelbaum & Fewster, 2004).

All in all, as mentioned in section 3.2, effective communication decisively encourages both team spirit and teamwork. In the cockpit, aircrews are expected to perform both teamwork and taskwork skills proficiently. Whereas being able to efficiently and effectively perform the task at hand is vital, teamwork skills are also critical for effective coordination and communication among crew members. A study conducted by Merkel and colleagues in 2000 indicates that failures in team performance skills played a significant role in aviation errors. They also pointed out that deficiencies in aircrew coordination skills, such as decision making and leadership, contributed to 68% of the mishaps examined in the study. Hence, understanding the role of teamwork skills beyond just taskwork is essential to aircrew performance and accident prevention (Salas & Maurino, 2010).

2.3.4 Motivation and Safety Behavior

It is widely known that within the airline industry, pilots' safety behaviors are regarded as important determinants of safety performance. Because a number of specific pilot behaviors have been considered as significant contributing factors to many air accidents, it is critical to identify the elements that may enhance the performance of these individuals concerning safety behaviors (Chen & Chen, 2014).

As we saw in the previous sections, teamwork plays a crucial role in the performance of air companies' staff. When faced with a changing environment, an organization needs to retrieve the old knowledge and create new knowledge to overcome the new challenges. Knowledge brokering is a key element in providing the necessary information to the company's staff at the right time so as to enable more effective teamwork. It is the process of connecting organizational members and building relationships that uncover shared needs and share knowledge (Lin, 2012).

According to Lin (2012), the relationships between organizational identification and organizational culture, and safety culture and safety behavior have been largely discussed in the aviation safety literature. In fact, the organization's culture is the source of safety culture that directly affects safety behavior. An important instrument to convey the safety culture, the safety mission statement, has a paramount influence on the pilot's safety behavior. A well-conceived mission statement can provide a common purpose, define the business scope, set standards for behavior, help employees identify with the firm, create shared values, and motivate and inspire organizational members.

Irrespective of how much effort the organization makes to set rules and procedures, and invest in technology to improve safety, the employee's level of identification can compromise by the effects of those efforts. Nevertheless, the mission statement can contribute to safety by motivating organizational members through values, beliefs, and guidelines. Hence, the organization’s managers should not only hone in on safety policy and technology but should also rethink the brokering knowledge process that may inculcate employees with the right concepts and behavior. Understanding the process of using the safety mission statement to change safety behavior can significantly increase the benefits of brokering knowledge (Lin, 2012).

In this work, we consider motivation as an internal condition that appears by deduction to initiate, activate, or maintain purposive behavior. Safety motivation refers to an individual’s willingness to make an effort to perform safety behaviors and the power associated with those behaviors. Therefore, people who are motivated to engage in safety behaviors are more likely to carry out these comportments (Chen & Chen, 2014).

Safety behaviors can be divided into two kinds: safety compliance and safety participation. Safety compliance represents the fundamental behaviors practiced by organizational members to ensure personal and workplace safety, which involves following safety procedures and carrying out tasks in a safe way. On the other hand, safety participation is the behaviors that help develop a safety-supportive environment rather than guarantee individual safety. Helping colleagues, championing safety programs, and volunteering for safety activities are considered as safety participation behaviors. Given the causality between motivation and behaviors, the stronger the safety motivation that pilots have, the more willing they are to practice safety behaviors (Chen & Chen, 2014).

One of the primary skills that pilots must have to exercise their profession is risk management. Pilots need to be able to manage risks by recognizing hazards, analyzing the risks involved, and making proper decisions based on this assessment. Risk perception and risk tolerance are essential aspects of risk management. Risk perception requires the detection of the risk associated with a situation or hazard. It is essentially a cognitive activity that can discern the risk inherent in a situation involving the accurate assessment of the external situation and personal capacities. The overestimation of personal capacities or the underestimation of the external situation can lead to a misperception of the risk and are frequently perceived as contributing factors of aircraft accidents (Pauley et al., 2008; Ji et al., 2011).

Risk tolerance refers to the amount of risk an individual is willing to take in a given circumstance. As a personality trait, risk tolerance is an essential issue for safety professionals since staff members often deal with workplace risks. Likewise, pilots are presented with opportunities to engage in risky behavior almost daily. Risk tolerance may be mediated both by the person’s risk aversion and his personal value attached to the goal of a particular situation. Some objectives may be perceived as worthy of higher levels of risk exposure than others. The high-risk tolerance can lead pilots to choose courses of action that unnecessarily expose them to hazards, and therefore, increase the likelihood of an air accident. In fact, both risk perception and risk tolerance may contribute to the implication of organizational members in risky behaviors and air accidents (Pauley et al., 2008; Ji et al., 2011).

In their study, Ji et al. (2011) examined the relative importance of risk tolerance, risk perception, and hazardous attitude concerning safety operation behavior in aviation in China. They aimed to integrate both social cognition and personality approaches so as to provide a better understanding of the mechanisms underlying pilots’ safety behavior. They concluded that pilots’ hazardous attitude plays a fundamental role in the relationship between risk tolerance and safety behavior - risk tolerance may directly influence a hazardous attitude that, in turn, may directly impact the safety operation. In other words, risk tolerance may indirectly affect safety operation behavior through its influence on a hazardous attitude.

It is fair to say that motivation is strongly affected by job satisfaction, which is an important contributor to many aspects of work performance. Several studies indicate that job satisfaction improves productivity and performance, whereas reducing absenteeism, turnover, and stress. Pilots have continuously faced the challenges of new technologies, more complex aircraft, large amounts of information, and steady growth in the number of daily flying activities. Not surprisingly, pilots’ job satisfaction levels are influenced by their routine efforts to cope with these challenging demands (Hoole & Vermeulen, 2003).

In their research, Hoole & Vermeulen (2003) investigated the relationship between pilot-related factors and the job satisfaction levels of aviators in South Africa. They found out that pilots involved in the area of passenger transportation and working for national airlines experience a higher level of job satisfaction. This is an important finding, considering that these pilots have a greater responsibility with regard to human life. One of the possible explanations is that pilots would rather fly in a more structured work environment with a clear set of rules and standard operating procedures (SOPs). The more "protected" environment offered by larger air companies results in higher pilots' job satisfaction, despite the long work schedules and irregular shifts. Other plausible reasons for higher job satisfaction are the possibility of interaction during flight, sharing responsibilities, more prestige, more promotion opportunities, and better remuneration.

2.3.5 Stress

Ebermann & Scheiderer (2013) define stress as the sum of all the stimuli influencing an individual. There are two kinds of stress – eustress and distress. Eustress is positive stress, which is required for maintaining a person's health. Distress is damaging stress, which permanently disrupts personal physical and mental equilibrium, damaging the person's health. Stress is experienced by each person differently and individually. One pilot may encounter eustress while the other one faces distress in the same difficult situation.

Currently, organizations and societies worldwide suffer losses of hundreds of billions of dollars due to stress and its consequences each year. This phenomenon has provoked an ongoing interest for decades now, and it has been assessed by scholars, journalists, policymakers, and practicing professionals in many fields of study (Tourigny et al., 2010).

Given that high levels of stress are a leading cause of errors in safety-critical industries such as nuclear power and emergency medicine, it is vital to gain a better understanding of how individuals perform in stressful environments. This is particularly pertinent within the field of aviation, where human error is the leading contributing factor to aircraft accidents (Vine et al., 2015). The Lufthansa study also indicated that 25 % of all accidents reveal symptoms of excess stress (Ebermann & Scheiderer, 2013)

Stress can be brought into the cockpit by the pilot's chronic conditions (life stress) or can be the acute stressors that develop within the flight (flight stress). Chronic stress builds over time due to persistent stressors, frequently external to the profession.

On the other hand, acute stress usually results from occupationally related stress peaks that can extend up to the limits of one's productive capabilities. Both types of stress are cumulative, adding to the total stress burden. A certain amount of stress is wholesome because it precludes boredom and complacency within the cockpit. However, excessive stress may have a negative impact on the pilot's attention to the relevant aspects of flying an aircraft (Ebermann & Scheiderer, 2013; Koonce, 2002).

The relationship between stress and performance have been the object of many studies over the last decades. The Yerkes-Dodson Diagram summarizes some of the studies' conclusions - every task requires a specific level of stimulated stress to optimally accomplish it (Figure 14). On the one hand, too few stressors may generate boredom, fatigue, frustration, or dissatisfaction. On the other hand, too many stressors may cause inadequate problem solving, exhaustion, illness, or low self-esteem. Optimal stressors provoke creativity, continued development, satisfaction, progress, and rational problem solving (Ebermann & Scheiderer, 2013).

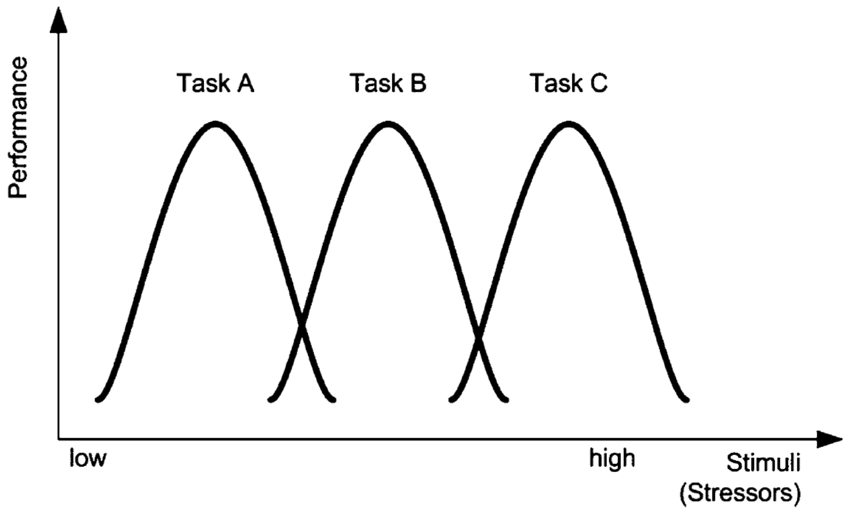

Figure 14. The relationship between stressors and performance. Note. Adapted from Ebermann & Scheiderer, 2013.

According to Anca et al. (2010), personal stressors include concern with family matters, job security, or health issues. Whereas some pilots can forget about these matters in the cockpit, others may be highly distracted by them. These personal factors may also affect decision making by interfering with sleep, which can have negative impacts on readiness, attentional focus, mood, and communication. Ill-structured problems and organization-related goal conflicts require high levels of cognitive effort, which may be compromised in conjunction with other stress factors. Stress typically stifles working memory capacity, thus limiting the pilot's ability to contemplate multiple hypotheses or to mentally simulate the consequences of options.

In the aviation industry, pilots are supposed to handle stress adequately. After all, their work conditions and tasks more often than not exhibit attributes of extreme stress. Stressors such as a high degree of responsibility, multiple burdens, time constraints, and an ever-changing environment, are intimately tied to this profession. However, when stress continues over an extended period, it dramatically reduces performance capabilities and threatens health. And when pilots reach their stress limits, they are no longer capable of making wise decisions, therefore, putting at stake their crew and aircraft. In fact, aviation safety experts have revealed that high levels of stress are a prominent cause of the pilot’s error (Ebermann & Scheiderer, 2013; Vine et al., 2015).

Flight-related stress plays a paramount role in CRM programs. In the cockpit, decision making, information processing, human error, and communication are not only influenced by too much, but also by too little stress. In fact, decision making is the most relevant driver of stress in the aircraft. The pressure associated with always needing to make adequate decisions under unpredicted and complex situations is one of the main sources of mental stress (Ebermann & Scheiderer, 2013).

According to the National Transportation Safety Board (NTSB), decision-making can be degraded when individuals are under stress because they selectively focus on only a subset of hints in the environment. In other words, stress narrows the span of attention, making individuals focus on the most salient aspects of threat, which is problematic when they need to integrate diverse information to evaluate the overall scenario. As a result, any situation assessment may be incomplete, and the resulting decision, even when made by an expert, may be degraded. Stress can also hinder an individual's ability to evaluate an alternative course of action, resulting in a tendency to proceed with an original plan even though it may not be adequate anymore (Dismukes, 2007).

The likelihood of pilots to engage in risky decision-making increases when time pressure becomes too strong. When these risky decisions then lead to failures, there is a tendency to try to master the situation at any cost, even to the extent of potentially disregarding standard operating procedures (SOPs). The crew then very quickly find themselves trapped in the so-called poor judgment chain. One indication that a crew has been subjected to high-stress levels is the decrease in verbal communication. The breakdown of communication is one of the most common contributing factors in the causal chain leading to air accidents (Ebermann & Scheiderer, 2013).

In their research, Vine et al. (2015) investigated the individualistic way in which stress influences human performance among pilots in the United Kingdom. They analyzed experienced and qualified pilot’s reactions to a simulated stressful incident and the influence of these reactions on attentional control and flying performance. They concluded that a threat response to stress (a situation in which the pilot considers that demands outweigh resources) provoke a more impoverished pilot's performance than a challenge-response (when the pilot thinks resources are sufficient to meet the demands of the situation). Moreover, a threat response is usually associated with disrupted attentional control.

It is well-known that airline employees suffer from chronic fatigue associated with heavy pressure and shift work. With the increment of demand for air travel in developing countries, where the airline industry is currently undergoing a significant expansion, employees suffer additional pressures to work more extended hours and to take on more responsibilities. Therefore, this can increase pilots' workload and time pressure. Moreover, such changes can provoke more stress due to increases in potential role conflict that results from the necessity to work on different shifts within different crews (Tourigny et al., 2010).

Rapid changes can also be associated with role ambiguity when employees take on additional responsibilities without receiving enough supervision on how to accomplish their tasks. Organizational growth frequently represents challenges concerning personnel recruitment, retention, and turnover to airlines. These challenges also contribute to role overload. Thus, it is worth understanding the factors that increase job stress and exploring how job design can be modified so as to mitigate stress and its consequences (Tourigny et al., 2010).

A fixed shift and a rotating shift have differential impacts on job stress. Shift work may cause sleep disturbances, which, in turn, can adversely affect moods and decision-making capacity. Sleep-deprived pilots tend to bypass rational calculation and take higher risks and to display lower response speed on psychomotor vigilance task. These conditions may contribute to the severity of operational errors associated with human factors in air companies. Rotating shifts add to higher levels of job stress in comparison to fixed shifts. Hence, shift work can interfere with decision-making processes, which are critical to aviation safety. Finally, research indicates that, for employees working on fixed shifts, high decision latitude significantly weakens the impact of role overload on job stress and that low decision latitude aggravates the relationship (Tourigny et al., 2010).

Even in wholly unusual and highly demanding circumstances, some pilots can adequately handle stress. That was the case of US Airways flight 1549 in January 2009. After experienced the loss of power of both engines during the takeoff, the pilot successfully managed to make an emergency crash landing on the Hudson River, saving all 155 passengers. In spite of the inevitable stress he experienced, Captain Chesley Sullenberger was able to remain focused, maintain the control of the aircraft, and perform an impressive emergency landing (Vine et al., 2015).

All things considered, the ability to cope successfully with stress is significantly relevant to airline pilots. In order to hone that skill, first, pilots need to have a good understanding of their reactions to stress and the correlation between stress and their performance. Then, they need to be able to distinguish between chronic and acute stress. Finally, pilots must benefit from stress management techniques and stress training programs to properly cope with stress (Ebermann & Scheiderer, 2013).

2.3.6 Fatigue

As we saw in section 1.1, over the last decades, the most common cause of aircraft accidents has been human error. And some studies point out that the most common cause of human errors is fatigue. In fact, aircrew members face long duty days, early departures, late arrivals, and non-standard work hours that include night duty and rotating schedules almost on a daily basis. Researchers suggest that aircrew fatigue is, therefore, a function of scheduling and workload (Koonce, 2002; Caldwell, 2005).

According to Wiegmann & Shappell (2001), one aeromedical factor that has received considerable attention over the last years is fatigue. As knowledge of the physiological foundations of circadian rhythms and disruption have developed, an awareness of the effect that such factors have on errors in both military and civilian aviation has increased. This growing recognition was reinforced by the National Transportation Safety Board (NTSB) ruling that classified fatigue as a causal, rather than contributory, factor in an airline accident — one of the first of such rulings in the history of the Board.

In a study conducted by the London School of Economics quality and the European Organization for the Safety of Air Navigation (EUROCONTROL), researchers found that pilots were often tired at work and felt that airlines did not take fatigue seriously. The conclusions raised concerns that pilots were overworked, particularly by budget airlines that regularly scheduled the same team on multiple flights on the same day (Patron, 2016).

The ICAO defines fatigue as a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety-related duties (ICAO, 2016).

The adverse impacts of fatigue on aviation are well known, as evidenced by both the number of fatigue-related mishaps and many studies that have demonstrated that most pilots experience a deterioration in cognitive performance and increased stress along with their flights. What's more, because of the characteristics of the average pilot's work schedule, with frequent changes, early morning starts, and extended duty periods, fatigue may be impossible to avoid altogether. Therefore, it is vital that fatigue countermeasures be available to aircrew members in order to help them to mitigate the often-overwhelming effects of sleep loss or sleep disruption (Hartzler, 2013).

In many high-profile accidents, fatigue effects such as lowered response times and the failure to pay attention or suppress inappropriate strategies have been identified during the investigations. In the aviation industry, flight fatigue alone might be a significant contributing factor to a large number of aviation accidents. However, it is complicated with the current accident investigation tools to positively identify whether or not fatigue was the cause of the associated accident (Yen et al., 2009; Lee & Kim, 2018).

2.3.6.1 Impact on Performance

A vast amount of scientific work in the past years has established that human fatigue is dynamically influenced by neurobiological regulation of sleep need and endogenous circadian rhythms, which interact nonlinearly to produce changes in human alertness and cognitive performance over time. (Salas & Maurino, 2010).

Fatigue provoked by sleep loss and circadian disruption can degrade or impair diverse aspects of human performance, including decision-making, attention, reaction time, learning, memory, communication skills, and situational awareness. In order to determine the occurrence of fatigue in recent relevant accidents, the NTSB carried out a comprehensive study that reviewed all major accident investigations completed between 2001 and 2012. Overall, fatigue was identified as the probable cause, a contributing factor, or a finding in 20% of these investigations. More importantly, fatigue was spotted in 23% of its major aviation investigations (Marcus & Rosekind, 2015).

With human alertness and performance modulated by sleep need and circadian rhythms, it is evident that human beings were just not designed to operate effectively under the pressure of 24/7 schedules. It is tough to eliminate fatigue from aviation operations due to the essential schedule requirements for trans meridian travel, irregular and unpredictable schedules, long duty days, early report times, night flights, and reduced sleep opportunities. The risk of performance impairment and fatigue caused by lack of sleep and working during circadian misalignment can then be further compounded if the individual has to work long duty hours or in an environment of a heavy workload (Salas & Maurino, 2010).

We should also bear in mind that there are individual differences in the extent to which fatigue affects performance, physiologic vigilance, and subjective signs of fatigue. These differences include the effects of sleep loss, nighttime work, individual sleep needs, and recovery times. Factors like age, sleep need, experience, and the overall state of health have a direct impact on these individual performance differences (Mello et al., 2008).

According to Salas & Maurino (2010), the biological basis of this differential vulnerability to sleep loss and circadian disruption is not known and may be genetic. The problem is that aircrew members are not really aware of their differential responses to sleep loss and circadian disruption. Moreover, subjective self-reports of fatigue and sleepiness often underestimate actual performance deficits from fatigue, which makes the task of preventing fatigue even more challenging.

Critical cognitive skills (judgment, decision making, perception, and memory), performance accuracy, reaction time, communication skills (including crew coordination), mood, situational awareness, and alertness are all vulnerable to fatigue. As a result of its effects on judgment, the degree of fatigue and subsequent performance decrements are frequently underestimated by aircrew (Hardaway & Gregory, 2005; Caldwell, 2005).

2.3.6.2 Fatigue Factors

In its Manual for The Oversight of Fatigue Management Approaches, ICAO (2016) categorizes fatigue factors into legal framework, commercial pressure, staff arrangements, staff demographics, acceptance of shared responsibilities for fatigue management, fatigue management structure, geographical location, level of isolation of professional during duty period, working condition, irregular operation, workload, interaction with other aviation professionals, experience level, and lifestyle influences.

In their research about the factors that affect airline pilot fatigue, Lee & Kim (2018) classify inherent pilot fatigue into three factors - physical fatigue, mental fatigue, and fatigue due to a lack of rest. They also shed light on the seven major items that increase pilot fatigue, and consequently reduce operational flight performance. The seven elements are deficient schedule operations, different flight directions, incorrect partnerships resulting from culture, inadequate aircraft environments, inappropriate job assignments, ethnic differences, and defective hotel environments.

2.3.6.3 Biological Regulation of Sleep, Alertness, and Performance

Circadian disruption, or jet lag, occurs when there is desynchronization between external time clues (sunlight, meal times, work schedules) and the internal physiologic clock, which regulates sleep-wake cycles, digestion, body temperature, cardiovascular function, renal function, and the release of certain hormones (prolactin, growth hormone, androgens, cortisol, insulin). Irregular work hours, night or swing-shift work, and fast trans meridian travel can all cause circadian disruption (Hardaway & Gregory, 2005; Salas & Maurino, 2010).

The internal circadian pacemaker modulates the daily impacts in many physiological and neurobehavioral functions, including alertness and sleep patterns. A second fundamental neurobiological process involved in the timing of alertness and quality of optimal cognitive performance is the homeostatic sleep drive, which interacts with the endogenous circadian pacemaker. The increase in homeostatic sleep drive with time awake (or inadequate sleep) and the circadian cycle interact to produce nonlinear dynamic changes in human fatigue and functional capability (Salas & Maurino, 2010).

Even though the alternation between sleep and wakefulness is precisely regulated, individuals frequently choose to ignore the homeostatic and circadian mediated signals for rest. This commonly occurs when the sleep-wake cycle is out of phase with the internal rhythms that are controlled by the circadian clock (during nightshift work or jet lag), provoking negative impacts on health and safety. In addition to circadian disruptions and acute or cumulative sleep deprivation, prolonged periods of continuous wakefulness contribute substantially to pilot fatigue (Caldwell, 2005; Salas & Maurino, 2010).

The synchrony of a person with both her external and internal environments is critical to the person’s well-being and behavioral efficacy. Disruption of this synchrony can result in a range of difficulties, including degradations in response accuracy and speed, unconscious acceptance of lower standards of performance, impairments in the capacity to integrate information, and narrowing of attention (Hardaway & Gregory, 2005; Salas & Maurino, 2010).

In fact, overly tired aviators may face operational risks similar to those posed by alcohol intoxication. Pilots flying at night or during the predawn hours are especially vulnerable to fatigue-related cognitive lapses, or even worse, “micro-sleeps”—brief periods during which sleep uncontrollably and often unconsciously intrudes into wakefulness. Psychological mood, self-reported alertness, central-nervous-system activation, and basic cognition were substantially impaired following 22 or more hours without sleep, and objectively measured piloting skills were degraded by more than 40 percent due to aviator fatigue (Wilson et al., 2007).

The demands of aviation operations continue to challenge the brain’s sleep and circadian systems, thus contributing to fatigue and increased performance risks in flight crew. This is further complicated by highly automated cockpits that require minimal interaction with aviation systems, which results in a high requirement for relatively passive vigilance in flight crews (Salas & Maurino, 2010).

2.3.6.4 Fatigue and Type of Operations

Flight operators usually classify aviation operations into three types: short-haul, long haul, and ultra-long range. Pilots are faced with fatigue-related operational challenges including irregular and unpredictable schedules, long duty days, early report times, night flights, reduced sleep opportunities and circadian disruption, and the extent to which these various factors are problems can vary as a function of the type of operation (Salas & Maurino, 2010). Long-haul pilots associate their on-the-job fatigue primarily with night flights and jet lag. In fact, aircrews serving on long-haul flights (with flight times exceeding six hours) tend to experience more problems with sleep loss and circadian rhythm disruption. Sleep quality, both at home and on board the aircraft, has been recognized as a significant factor affecting the fatigue level of long-haul crews (Salas & Maurino, 2010; Yen et al., 2009).

On the other hand, short-haul pilots attribute their fatigue-related problems more to prolonged duty periods and early wake-up times. Crews serving short-haul flights (with flight times of less than two hours) have reported that schedules consisting of 4 or 5 legs of flight are the most fatiguing schedules to fly. They tend to suffer from fatigue due to early departures, late finishes, and intensive takeoff and landing procedures that are workload demanding. Pilot's age and the relatively cramped cockpit environment of these short-range aircraft are the most significant negative fatigue factors. For regional flight crews (flight times between two and six hours), the factors that cause fatigue tend to vary with the individual. (Caldwell, 2005; Yen et al., 2009; Salas & Maurino, 2010).

2.3.6.5 Workload

There is plenty of evidence to show that the aviation environment is particularly sensitive to both the development and effects of fatigue due to operational tempos driven by economic and political factors. These factors combine with the modern automated "glass cockpit" filled with sophisticated electronics and increasingly crowded airways, both of which require a high degree of vigilance and technical skills on the part of the aircrew (Hardaway & Gregory, 2005).

The aviation industry seeks to manage fatigue, considering the current demands of 24-hour operations. Any activity that requires aircrew members to maintain high levels of alertness over extended periods (16 hours) or at a circadian phase that permits sleep to occur (biological night) is exposed to the neurobehavioral and cognitive consequences of sleep loss and circadian disruption. Hence, long duty periods contribute to sleep deprivation, and working around the clock is complicated by circadian factors (Caldwell, 2005; Salas & Maurino, 2010).

According to Salas & Maurino (2010), although fatigue can result from sleep loss and circadian disturbances, it can also occur due to the excess of cognitive or physical workload. The risks of accidents and injuries increase as workload increases — especially after more than 12 daily hours of work or more than 70 weekly hours of work, which is why US federal statutes and regulations have historically limited duty-hours in all transportation modes and other safety-sensitive industries.

2.3.6.6 The Main Problem Regarding Fatigue

Over the last years, the relevant scientific knowledge related to fatigue, sleep, circadian rhythms, and sleep disorders has grown enormously. There has also been a parallel increase in investigators' recognition that fatigue can have a causal or contributory effect on human performance, leading to errors, crashes, and other unsafety events. Besides, new investigative techniques have been developed and are now standard components of significant investigations. These advancements in science, recognition, and investigative techniques have resulted in fatigue findings that otherwise might not have been identified (Marcus & Rosekind, 2015).

However, we should take into account that it is often difficult to identify fatigue as a contributing factor in aviation mishaps due to two main reasons. First, sleep is often considered to be an option and not a necessity in our 24-hours, 7-day work society. There is a tendency to underreport fatigue because it is commonly seen as a personal weakness and not as a natural result of scheduling and operational tempo, poor nutrition, sleep disorders, circadian desynchronosis, or workplace and personal stress. Second, memories of the circumstances surrounding an aviation incident or accident are often fragmentary or faulty and are dependent on subjective perceptions surrounding a traumatic event. Because of these misconceptions and the intrinsically subjective nature of much of the subsequent human-factors investigations, fatigue is more often than not merely grouped with human error on official reports (Hardaway & Gregory, 2005).

2.3.6.7 Fatigue Risk Management Systems

Caldwell (2005) argues that scheduling demands and human physiological makeup are at the heart of fatigue-related problems in aviation. The multiple flight legs, long duty hours, limited time off, early report times, less-than-optimal sleeping conditions, rotating and non-standard work shifts, and jet lag that have become so common throughout modern aviation pose significant challenges for the fundamental biological capabilities of pilots and crews.

Many aviation industry practices induce fatigue through sleep loss and circadian misalignment in aircrews. Thus, it is necessary to develop scientifically valid fatigue-management approaches so as to mitigate sleep loss, enhance alertness during extended duty periods and cope with circadian factors that are primary contributors to fatigue-related aviation mishaps (Salas & Maurino, 2010).

Because of the potentially catastrophic effects that can result from a lapse in judgment on the flight deck, the aviation community has been introducing fatigue countermeasures as a means to improve flight crew performance. Preventative strategies are designed to limit sleep loss and circadian disruption. Operational procedures are intended to assist individuals in coping with ongoing fatigue while in the cockpit. Fatigue countermeasures include minimizing sleep loss, scheduling appropriate work and rest periods, napping, and education and are indispensable for matching fly crew members' capabilities to increasingly difficult job pressures (Caldwell, 2005; Hardaway & Gregory, 2005).

Fatigue Risk Management Systems (FRMS) potentially offer non-prescriptive approaches for addressing the complexity of aviation operations and fatigue challenges associated with aviation operations. FRMS strives to be evidence-based, and it includes a combination of processes and procedures that can be employed within an existing Safety Management System (SMS) for the measurement, mitigation, and management of fatigue risk. FRMS programs provide an interactive way to address performance and safety levels of operations on a case-by-case basis (Salas & Maurino, 2010).

Educational efforts are essential for ensuring a thorough understanding of the causes and effects of aircrew fatigue. In other words, education about the dangers of fatigue, the roots of sleepiness on the flight deck, and the importance of sleep and proper sleep hygiene is one of the keys to addressing fatigue in operational aviation contexts. Pilots and operations managers (those accountable for scheduling routes and missions) must be convinced that sleep and circadian rhythms are essential, and that quality off-duty rest is the best possible protection against on the job fatigue (Caldwell, 2005).

2.3.6.8 Regulations

One of the most difficult issues in work-rest regulations is the question of how much rest or time off work should be provided to shy away from the accumulation of fatigue. The common knowledge is that 8 hours for rest between work periods will result in an adequate recovery, which is normally stated in many work rules. However, aircrew members seldom use every minute of non–work time for sleep. As a result, sleep appears to account for about 50% to 75% of rest time in a daily off-duty period, which means that 8 hours off-duty allows for only about 4 to 6 hours of adequate sleep in most individuals (Salas & Maurino, 2010).

The prevalence of fatigue in aviation operations, as shown by numerous operational evaluations and research studies, indicates that the current prescriptive approaches have not entirely addressed sleep and circadian challenges associated with 24/7 operations yet. The root of the problem is that the dominant model of fatigue at the time the regulations were created many decades ago was a time-on-task theory that attributed all fatigue to prolonged periods of work, rather than to sleep loss and circadian misalignment, which are now known to be the primary causes of fatigue in commercial aviation (Salas & Maurino, 2010).

Nonetheless, in order to overcome that hurdle, in the United States and European Union, new flight regulations and flight time limitations (FTLs) have been implemented by the FAA and European Aviation Safety Agency (EASA), respectively. Training and education have been conducted with flight crews for fatigue risk management to integrate scientific knowledge into the FTLs (Lee & Kim, 2018).

The evolution of regulatory arrangement from unidimensional hours of service regulations to a framework that enables multi-dimensional FRMS reflects advances in the understanding of human error in the etiology of accidents, and fatigue and safety science. FRMS implementation shifts the focus of responsibility for safety away from the regulator towards companies and individuals and requires changes in traditional roles (Gander et al., 2011; Lee & Kim, 2018).

The FRMS concept has been introduced in the transportation sector since the beginning of the century in a series of regulations that tried to limit working hours in rail, road, and aviation operations. This approach reflects an early understanding that long unbroken periods of work could produce time-on-task fatigue and that sufficient time was needed to recover from work demands and to attend to non-work aspects of life (Lee & Kim, 2018).

Innovative ways to detect fatigue in human operators have been the focus of considerable research on technologies that validly and reliably predict, detect, and/or prevent performance risks due to fatigue. The fact that the generation coming into power over the next years grew up immersed in technology indicates that the realization of this technology in commercial aviation is inevitable. They accept human-machine interaction in nearly all aspects of life. In their minds, computers should be sentient-like, capable of reading human intentions, anticipating human actions, for instance. Those expectations will bring the emergence of ever-more sophisticated human-machine interfaces, which will change the nature of human work in all transportation modes, including commercial aviation. Fatigue is an area where such human-machine interfaces can have a profound effect by preventing, predicting, detecting, and mitigating fatigue-related risks (Salas & Maurino, 2010).

2.3.7 Human Error in Aviation

2.3.7.1 Unsafe Acts

One could reasonably acknowledge that most errors are insignificant and quickly forgotten. The relatively minor consequences of most human errors justify the relative inattention we pay to them. Some circumstances even ask for mistakes, such as when learning new skills. Designers and training professionals, recognizing the value of errors in learning environments, have developed system simulators that enable operators to be trained in operating systems in realistic situations, free of the consequences of failure. Therefore, what ultimately differentiates errors are their contexts and the relative severity of their consequences (Strauch, 2017).

As to the aviation domain, Wiegmann & Shappell (2001; 2003) argue that as aircraft have become more reliable and the technology in the cockpit has improved, humans have played a progressively more critical causal role in aviation accidents, resulting in the proliferation of human error frameworks and accident investigation designs.

According to Reason (1997), the term 'human error' communicates the impression that all unsafe acts can be consolidated into a single category. However, errors may take different forms, have different psychological origins, occur in different parts of the system, and require different methods of management. What’s more, this statement fails to recognize that people's behavior within hazardous systems is far more constrained than it is in other regular organizations. As a matter of fact, managerial and regulatory controls tightly govern the actions of pilots, ships' crews, and control-room operators.

Nowadays, within the aviation safety community, the term human error is often considered an unhelpful and reductive label misused to identify the solitary person(s) as the weak link in the chain of a complex system comprising many people, tools, tasks, policies, and procedures (Dekker, 2014; Miranda, 2018).

In fact, it is generally agreed that accidents are rarely, if ever, caused by a single factor but rather by a complex interaction of multiple factors, combining in ways driven in large degree by chance, each factor influencing the effects of the others (Reason, 1997).

Reason (1997) defines human error as the failure of planned actions to achieve their desired ends, without the interference of some unforeseeable event. Strauch (2017) has a similar view, considering human error as the result of something that people do or intend to do that leads to outcomes different from what they had expected. In other words, an error is an action or decision that results in one or more unintended negative outcomes. A summary of the psychological varieties of unsafe acts, classified initially according to whether the act was intended or unintended and then distinguishing errors from violations, is presented in Figure 15 as Reason's basic error types.

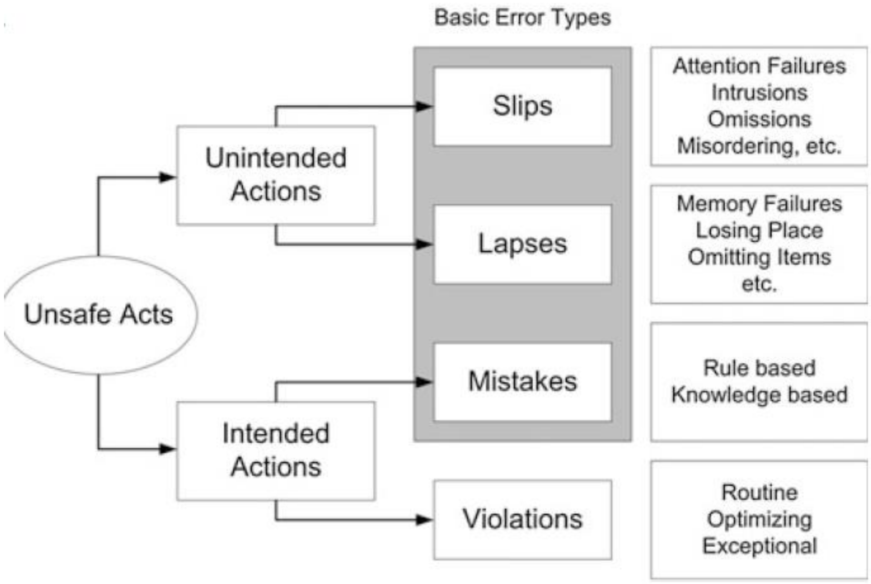

Figure 15. Reason's basic error types. Note. Adapted from Ebermann & Scheiderer, 2013.

Unsafe acts are divided into two categories - errors and violations. Errors are unintentional deviations from correct action, while violations are deliberate deviations from rules or instructions. Errors are further delineated into two subcategories: performance-based errors (PBE) and judgment and decision-making errors (JDME). PBE occurs when there is a failure of the basic skills that are performed without significant conscious thought. JDME, on the other hand, are considered "honest mistakes." They are consequences of intentional behaviors and choices that turn out to be inadequate for the situation (Reason, 1997; Wiegmann & Shappell, 2001; Miranda, 2018).

Strauch (2017) argued that there are only two important types of human error - action errors and decision errors when it comes to aviation incident or accident investigation. In an action error, an operator does something wrong or does something contrary to company procedures. Decision errors refer to incorrect decisions that operators make. In general, errors related to equipment control design antecedents tend to be action errors. Errors that call for interpretation, such as navigation or understanding the meaning of multiple alarms, tend to be decision errors.

Yan & Histon (2014) identifies in his research study that over the last years, more violations have been caused by pilots' failure to follow regulations and SOPs. They were aware of those rules but have decided to accept the risks of non-compliance. Since incident data is also used in that study, one possible explanation is that more violations are committed in incidents because the crew believed that a slight deviation from the rules would not be a big problem (i.e., lead to an accident). However, these actions have the potential to generate more severe outcomes under certain conditions.

2.3.7.2 Old View and New View on Human Errors

Dekker (2014) argues that there are two ways of assessing human error. The first view is known as the Old View, also called the Bad Apple Theory. As described in Figure 16, the Old View maintains that complex systems would function adequately, were it not for the erratic behavior of some unreliable people in it. In other words, it is the human errors that cause accidents. Those failures are unexpected and do not belong to the system. However, they are introduced to the system by people. That Old View maintains that safety problems are the outcome of a few bad apples in an otherwise safe system. These organizational members don’t always follow the rules, nor always watch out carefully. Hence, they end up creating organizational safety problems by undermining the whole system.

Strauch (2017) corroborates with Dekker’s concepts by adding that in complex systems, operator errors are the logical consequences of antecedents or precursors that had been present in the systems. Only recently, safety professionals have been considering system antecedents to play a significant role in error causation (Strauch, 2017).

The New View, in contrast, understands that systems are not basically safe. Actually, safety needs to be created through practice by organizational members. The aviation industry has made huge strides in safety since it embraced the New View. In this view, errors are symptoms of trouble deeper inside a system. Errors are the other side of people pursuing success in an uncertain, resource-constrained environment (Dekker, 2014).

Moreover, the behavior which we call ‘human error’ is not a cause of the organizational malfunction. It is just the consequence, the symptom of trouble deeper inside the organization. The New View assumes that people do not come to work to do a bad job. Undesirable outcomes are generally correlated to the conditions in which organizational members work. The organization may well have helped create those conditions. If those conditions are kept in place, the same unsatisfactory outcome may happen again, no matter how many sanctions are imposed or safety campaigns are carried out by the company (Dekker, 2014).

Old View	New View
'Human error' is the *cause* of trouble	What we call 'human error' is a *symptom* of deeper trouble
'Human error' is a separate category of behavior, to be feared and fought	'Human error' is an attribution, a judgment that *we* make after the fact
'Human error' is the target; people's behavior is the problem we need to control	Behavior is systematically connected to features of people's tools, tasks and operating environment
'Human error' is something to declare war on. People need to practice perfection	'Human error' is information about how people have learned to cope (successfully or not) with complexities and contradictions of real work
'Human error' is a simple problem. Once all systems are in place, just get people to pay attention and comply	A 'human error' problem is at least as complex as the organization that helps create it
With tighter procedures, compliance, technology and supervision, we can reduce the 'human error' problem	With better understanding of the messy details of people's daily work, we can find ways to make it better for them
We can, and must, achieve zero errors, zero injuries, zero accidents	We can, and must, enhance the resilience of our people and organization

Figure 16. The contrast between the Old View and the New View of 'human error.' Note. Adapted from Dekker, 2014.

We should bear in mind that errors in complex systems that lead to accidents and incidents are often preceded by extensive periods (incubation periods) in which the latent errors or organizational shortcomings gradually increase but remain unrecognized. These shortcomings may be underestimated or are undetected over time as the risks increase, and the organization gradually drifts toward an accident (Dekker & Pruchnicki, 2014).

2.3.7.3 Vulnerability to Error

Many people assume that if an expert in some field (aviation, medicine, or any other) makes an error, this is evidence of a lack of skill, situational awareness, or conscientiousness.

However, this assumption is both simplistic and wrong (Dismukes et al., 2007; Dekker, 2014).

Of course, skill, situational awareness, and conscientiousness are fundamental for safe, effective performance but are not sufficient. An especially problematic misconception about the nature of skilled human performance is that, if experts can usually perform some task without difficulty, then they should always be able to accomplish that task correctly. But in fact, experts in all domains, from time to time, make inadvertent errors at tasks they normally perform without difficulty. This is the outcome of the interaction of subtle variations in task demands, incomplete information available to the expert performing the job, and the inherent nature of the cognitive processes that enable skilled performance (Dismukes et al., 2007).

To protect and improve aviation safety, we must understand what makes pilots vulnerable to error and must comprehend the interplay of factors contributing to that vulnerability. To do that, it is vital to assess the nature of the vulnerability of pilots and other experts to error when performing tasks at which they are highly skilled. In fact, human skills and vulnerability to error are closely linked through underlying cognitive processes. In no small degree, the mistakes made by experts are driven by four factors: specific features of the tasks performed; events in the environment in which functions are performed; demands placed on human cognitive processes by task characteristics and environmental circumstances; and social and organizational factors that influence how a representative sample of experts would typically operate in particular situations (Dismukes et al., 2007).

In attempting to understand the errors made by expert pilots, it is crucial to avoid hindsight bias, a term that cognitive scientists use to describe distortion of evaluators' judgments by knowledge of the outcome of the situation that is being evaluated. Recognizing the catastrophic result of a flight makes it easy to identify things the crew could have done differently to prevent the accident. However, accident crews cannot foresee the outcome of their flights as far as they can tell, up until the moment when things start to go wrong, they are conducting flights as routine as thousands of times they have flown before (Dismukes et al., 2007; Dekker, 2014).

Thus, it is essential to understand the true nature of vulnerability to an error in order to reduce that vulnerability, to devise strategies and methods to help pilots catch errors before they become consequential and to make the aviation system resilient to errors that are not detected (Dismukes et al., 2007).

Strauch (2017) argues that, with certain exceptions, as a task becomes more complex and more people are needed to perform it, opportunities for error increase. Put differently, the more complex the work, the higher the likelihood that an error will happen, and the more people involved in performing a task, the greater the probability that an error will occur. Nonetheless, of course, people behave rationally and operate systems in a way to shy away from accidents. Systems that people design, manage, and run, are not immune to the consequences of error. Since organizational members are not perfect, designers and managers cannot design and supervise an ideal system, and operators cannot ensure error-free performance. Operators of any system, regardless of its complexity, purpose, or application, commit errors. Although errors cannot be eliminated entirely, opportunities for failure can be reduced. Therefore, the task of aviation safety investigators is to determine the cause of errors so that modifications to the system can be proposed, and the circumstances that led to the errors can be precluded from recurring.

2.4 Managing Human Factors in Aviation

Human Factors management in aviation seeks to mitigate safety risks before they result in aviation mishaps proactively. Through the implementation of safety management, organizations can manage their safety activities in a more disciplined, integrative, and focused manner. Possessing a clear understanding of its role and contribution to safe operations enables an organization to prioritize actions to address safety risks and more effectively manage its resources for the optimal benefit of aviation safety (ICAO, 2018).

2.4.1 Aircrew Selection and Training

2.4.1.1 - Developing Skills

Highly skilled professionals are fundamental for any airline to operate efficiently, safely, and with satisfied clients. As to employees, it is essential to have a job that is sufficiently challenging, where they are appreciated and rewarded according to the proficiency with which they perform their tasks. In order to achieve those goals, airlines need to have both a good selection system and an effective training program for candidates who have been selected. A successful selection process will lead to lower dropout rates during training and

an increase in the number of applicants completing the program (Martinussen & Hunter, 2017).
Over the last years, we have witnessed an increased interest in pilot selection by airlines, especially after the Germanwings accident in 2015, where the co-pilot intentionally crashed the airplane. The investigation board appointed by EASA had as one of its recommendations that commercial pilots should undergo a psychological evaluation as part of training or before joining service (Martinussen & Hunter, 2017).
Damitz et al. (2003) suggest that, over the last decades, it has been noticed that the performance of pilots in multi-pilot airline operations does not depend on their technical knowledge and flying skills alone, but also characteristics related to their personality and non-technical skills. Those features include attitudes, personality traits, and abilities that define both the interactions among a cockpit crew and performance-related aspects of teamwork, such as group decision making and workload management.
Damitz et al. (2003) also pointed out that research suggests that airline pilots consider specific abilities, knowledge and interactive/social factors, such as stress resistance, cooperation, communication, decision making, leadership, self-assessment, behavior flexibility, and social sensitivity, essential for their daily job demands in the cockpit.
According to Martinussen & Hunter (2017), research studies suggest that many cognitive abilities are relevant or highly relevant to the performance of civilian pilots, as well as psychomotor and sensory abilities. Within the cooperative/social skills domain, coping with stress, communication, and decision-making are also identified as paramount.

2.4.1.2 CRM Training

The importance of those non-technical behavioral qualities for pilot performance has already led to significant innovations in pilot training. This is reflected in the incorporation of CRM training in the training programs of almost all major airlines around the world. In reality, CRM is a comprehensive system of applying human factors concepts to improve crew performance. Moreover, interpersonal attitudes and skills and personality characteristics of pilots have also been considered during the process of pilot selection. However, we should bear in mind that even though interpersonal and teamwork attitudes and skills might successfully be trained to some extent, the modifiability of personality-related aspects of pilot behavior is limited, especially under the usual time restrictions of airline training. Thus, pilot performance and the effectiveness of CRM might capitalize on screening (student) pilots who already possess some basic attitudes, skills, and personality attributes that seem to be desirable for effective teamwork and crew coordination on the flight deck. (Damitz et al., 2003; Martinussen & Hunter, 2017).

Hoermann & Goerke (2014) highlight that, in a research study carried out in Lufthansa German Airlines, it was observed that social factors in the cockpit play a more relevant role in the incidence, risk, and mastery of safety-related incidents than operational and technical issues. However, the appropriate amount of these nontechnical skills is neither assured by an air-transport pilot license, nor is it acquired with increasing flight time or rank. That is why regulators began to make mandatory that airlines systematically train pilots and other crew members in subjects such as CRM, multi-crew cooperation, and human performance and limitations.

The concept of CRM began decades ago when a NASA workshop discussed the role of human error in air crashes. Since then, CRM has continued to evolve and, although there are no definitive data to link it to reduced error, its validity has been accepted by a vast part of the industry, and it is now an integral component of flight training. From a practical standpoint, it focuses on educating crews about the limitation of human performance, and how stressors such as fatigue, emergencies, poor communication, and work overload contribute to errors being made. According to the CRM concept, mitigating the circumstances in which these human errors occur should result in fewer aviation incidents and accidents (Seager et al. 2013).

There is plenty of evidence to show that CRM has positively affected the aviation industry for more than 30 years and has become an integral part of the professional culture of pilots. However, on the individual level, it cannot be assumed that current CRM training programs alone can sufficiently compensate for some pilots' lack of social competence. What`s more, some recent studies pointed out that the statistical impact of CRM training on the attitudes and behaviors of the participating crew members remained vague (Hoermann & Goerke, 2014).

Nonetheless, the most modern versions of CRM training are distinguished by a focus on error management. The ultimate purpose of that last generation of CRM, which should be reflected in the training syllabus and the training exercises, is to develop effective means to mitigate risks. This philosophy reflects the Reason (1997) model of accident causality (mentioned in section 1.2.2), in which it is admitted that perfect barriers against accidents do not exist. In other words, despite the best-laid plans and best-designed systems, there will inevitably be failures, mistakes, and errors. Thus, it is prudent to train to expect, recognize, and manage those risks (Martinussen & Hunter, 2017).

CRM training is even a more powerful tool when associated with Line Oriented Flight Training (LOFT). This training technique continues to offer high potential returns in training and safety, creating in simulators the most realistic flight scenarios possible, where aircrew performance will more closely match that seen in the operational environment. Simulator video equipment used in LOFT is becoming standard, fitting together with crew performance and analysis systems (Salas & Maurino, 2010).

In order to predict pilots` career development beyond the completion of the initial training, it is essential to include measures of social competence in addition to cognitive tests in pilot selection procedures. Social competence is a vital requirement (not just “nice to have”) for the profile of an airline pilot and future captain. Hence, it should receive more attention to selection and training. Traditional pilot training is still mostly technical and procedure-oriented, and to a much lesser extent, directed toward systematic development of nontechnical skills. Including proper psychometric measures for social competence as part of the selection procedure can guarantee a higher level of proficiency in this area right from the start. Together with following CRM training, this could contribute to long-term success in a pilot’s career. However, suitable methods need to be customized to the airline’s specific needs, and the additional resources that would be required for test administration, including expert personnel, have to be provided (Hoermann & Goerke, 2014).

2.4.1.3 The Importance of Training

As advances in airline technology continue to strengthen the safety system, and the demand for air transportation continues to increase, the human part of the system becomes increasingly exposed to growth-related threats. The probable doubling of fleet size in the next years will result in more accidents if aviation safety performance doesn`t improve considerably. That is why the maintenance of the current remarkably low accident rate is not enough. The rate has to be reduced further. Optimize pilot training presents an excellent opportunity to pave the way to achieve this challenging goal in the future (Salas & Maurino, 2010).

The concepts and fundamentals of human factor training in aviation can also be applied in other spheres of activity and study. Seager et al. (2013) draw a parallel between aviation and surgery to emphasize the advantages that human factor training can bring to different fields. Both areas require the use of technology, involve highly specialized professional teams, and deal daily with risk and uncertainty. Unlike commercial aviation, the importance of human factors is not completely entrenched in other areas, such as medical or surgical practice, although they have become more accepted in recent years.

In aviation, training has been developed to improve air safety by strengthening human factors such as communication, decision-making, and leadership, all of which are important in teamwork. Several studies have highlighted a similar need for improved teamwork in healthcare and have explored the concept of adopting practices from CRM to improve safety for patients. Implementing the human factor approach - peer monitoring, briefings, defining standards, recognition of fatigue as a factor in performance, check rides, the blame-free culture of accident investigations, checklists, application of “sterile cockpit,” to name a few; can dramatically improve safety not only in aviation but also in other risky areas such as surgery (Seager et al., 2013).

Required flying skills have considerably changed from sharp handling and control manipulation to the use of automation designed into the aircraft systems. That is why the quality and relevance of training has had to evolve not only with the technological advancements but also with the changing profile of the traditional airline pilot. The challenge for pilot training systems is to keep pace with changing programs and train to sufficient standards in ever-decreasing time. In any commercial environment, there are always some financial constraints on the extent of training and ensuring the excellent training standard is most challenging when there are restrictions on how much one can train. Therefore, training must include a follow-up process to control and measure the effectiveness of each program, identifying high-value priorities to address. The training provider is tasked to deliver just the right amount of training without having to expend higher costs while achieving the objective of delivering each pilot with the excellent knowledge and skills for performing the tasks (Salas & Maurino, 2010).

In spite of the incredible innovations in aircraft automation and the consequent change in the required flying skills, Cui & Li (2015) found out, in their research on Chinese airline companies, that technology development is not the most critical factor affecting the civil aviation safety efficiency. Instead, they came to the conclusion that the essential element for safety proficiency in airline companies is investments in training and honing the skills of aviation safety staff and airline pilots. The results of their study indicate that the most significant and challenging task is to attract and train more aviation safety talent and more airline pilots.

Training is one of the vital constituents of a Quality System process (we will discuss this subject in section 4.4), delivering the end product of a competent pilot, cabin crew, or engineer to meet the demands of a critical role. The process of training an aircrew can be seen as a virtuous cycle, divided into the following phases: selection, training, monitored performance, evaluation, re-training, and so on.

Training must be an integral part of a comprehensive quality process, incorporating measurable performance indicators to determine the standard of practice being delivered. In this sense, an effective training program must have a quality assurance process to assess its performance continuously. This process should become part of an overall safety management system where training is at the forefront of delivering safe operations (Salas & Maurino, 2010).

Finally, Salas & Maurino (2010) argue that the association of QA and modern training frameworks and techniques have been dramatically improving aviation safety over the last decades. Threat & Error Management (TEM) is a useful framework on which to hook better pilot training practices. Pilots need to be taught to detect, avoid, and trap system threats continuously within the training process. Well-trained pilots are produced via well-established educational principles, but to more effectively deliver the necessary knowledge, skills, and attitudes, it is necessary valid tools, people, and processes.

Whereas modern CRM training continues to provide key guidance on effective communication, task sharing, team building, and teamwork; TEM training promotes preemptive strategies of threat recognition, avoidance, and management. The TEM working model is based on the assumption that it is a combination of the ability of a crew to prepare for threats and properly manage errors that will enable them to handle complex, non-standard, or massive workload situations efficiently. Both CRM and TEM should be driven by relevant data sources, such as incident and accident investigation reports, Flight Operations Quality Assurance (FOQA) programs, Line Operational Safety Audits (LOSA), and Aviation Safety Action Program (ASAP) (Salas & Maurino, 2010; Stolzer et al., 2008). We will further discuss these programs in section 4.2.

2.4.1.4 Impact on Performance

Reaching high levels of performance and safety in all situations is of fundamental importance in dangerous work environments such as aeronautics, the nuclear industry, or medicine. The issue of how to maintain adequate performance when faced with unusual situations is thus currently a focus of attention in these organizations. Not only must operators be able to manage expected circumstances wisely, but they must also be able to handle unforeseen situations (Vidulich et al., 2014).

Charness & Tuffiash (2008) suggest that understanding the mechanisms that underlie expert performance provides insights into the structuring of better training programs for improving skills and in designing systems to support professional expertise. They pointed out that modern researchers begin their studies by constructing representative tasks on which superior performance can be directly observed.

In some cases, the representative task can be sampled directly from real-world situations. Research results show that many experts report having experienced extended training and/or apprenticeship (a decade or longer) before their attainment of superior performance. One possible explanation of the development of skill during this period is the concept of deliberate practice – challenging activities designed to target and correct specific weaknesses in performance skills. The consequences of extended engagement in deliberate practice are quantitative and qualitative changes in cognitive representations of task-relevant knowledge, which will ultimately lead to sizable improvements in performance.

All in all, given the diversity and complexity of operational situations and systems, it is currently accepted in civil and military aviation that one cannot train for all cases. It is agreed, nowadays, that it is essential to reinforce the preparation of pilots to manage complex and unforeseen scenarios. Organizations and individuals in charge of the training of operators engaged in risky activities have to deal with an intriguing contradiction. On the one hand, safety specialists have to design training programs that make it possible to teach pilots to mitigate risks by following procedures and routines that guarantee continued safe operations. On the other hand, they must develop adaptability, the ability to detect and identify unexpected circumstances, and then to process these situations by identifying new solutions while maintaining safe operation (Vidulich et al., 2014)

2.4.2 Safety Management

2.4.2.1 The Evolution of Safety Thinking

The SMS has been extensively utilized as a tool to gauge safety and comply with regulatory requirements in many technologically advanced fields, such as energy production, oil and gas industry, and process systems. The introduction of SMS in the real operational environment has become a critical factor in aviation safety. The profound cultural change and effort that the employment of an SMS requires, at the economic and organizational level, represent a considerable challenge for the aviation industry (Cacciabue et al., 2014).

The aviation industry categorizes safety management methods into three different main approaches – reactive, proactive, and predictive aviation safety. Reactive aviation safety is based on incident and accident aviation investigations. The idea is to investigate previous mishaps so as to prevent future ones. The future accidents that are to be precluded do not necessarily have to be similar to the one that is being investigated. The primary objective of investigating accidents is identifying hazards. Once those hazards are discovered, safety experts need to address them through safety risk management, whether they actually were important to the accident in question or not, since they could provoke future disasters. Put differently, finding, evaluating, and controlling safety-related hazards contribute enormously to accident prevention (Stolzer et al., 2008; Cusick et al., 2017).

The second aviation safety approach – proactive, uses inferential analysis to describe a potential reality that has not yet manifested. In this sense, the “big data” revolution that continues to impact almost all industries may give its contribution to aviation safety. Increasingly, managers both within and outside of aviation safety circles are demanding more specialized information to make informed and sound decisions. Aviation has relied heavily on data and recommendations from the painful and lengthy process of accident investigations to make safety improvements. Although that approach has worked very well, commercial aviation now faces what can be called an intriguing dilemma. There are no longer a sufficient number of serious accidents to provide continuous and significant improvements to safety. However, there are many hazards and risks to aviation operations, yet the scarcity of accidents requires a proactive approach. Those hazards can be unveiled through observation and analysis techniques known collectively as proactive safety. It means that safety personnel can identify hazards that may not be obvious before they trigger an accident with disastrous consequences for the company (Stolzer et al., 2008; Cusick et al., 2017).

The third approach - predictive safety, refers to the investigation of potential hazards that do not yet exist, but that might cause damage the very first time they make an appearance. It relies on probability and severity as critical input variables. Some aviation safety experts believe that predictive safety is a key missing dimension of many SMS safety risk management and safety assurance programs. They argue that any successful effort to further lower accident rate must attempt to tackle hazards before they present themselves, in addition to relying on the reactive and proactive dimensions of safety. Figure 17 shows the safety management continuum - a summary of those aviation safety approaches (Stolzer et al., 2008; Cusick et al., 2017).

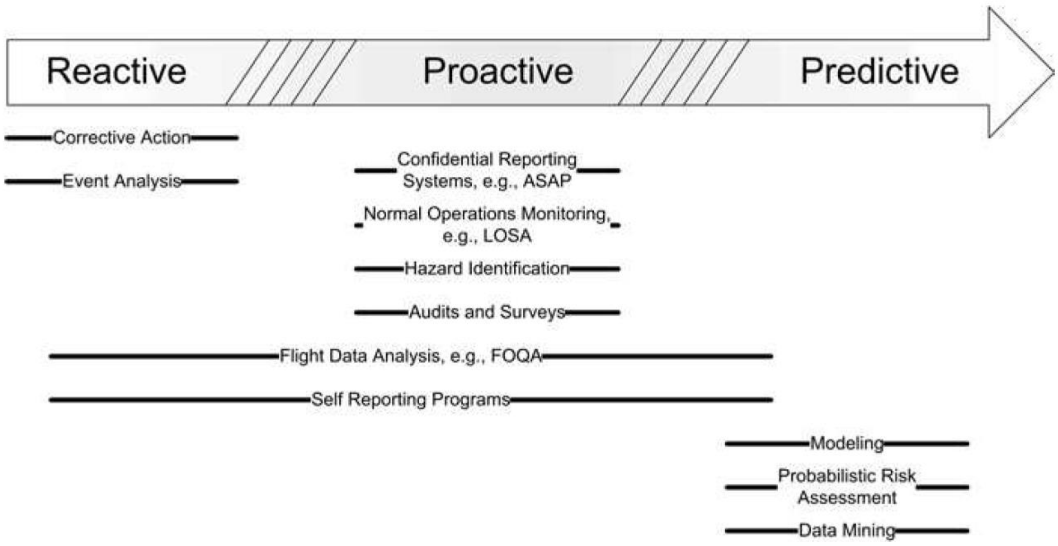

Figure 17. Safety Management Continuum. Note. Adapted from Stolzer et al., 2008.

2.4.2.2 Safety Management System and Programs

According to ICAO (2013), a safety management system is a systematic approach to managing safety, including the required organizational structures, accountabilities, policies, and procedures. In other words, it is a dynamic risk management system based on quality management system (QMS) principles in a structure scaled appropriately to the operational risk, employed in a safety culture environment (Stolzer et al., 2008).

According to Muller et al. (2014), a safety management system is a set of processes or elements that combines operational and technical systems with financial and human resource management. It is a systematic approach to safety with the focus on goal setting and a clear definition of accountability throughout the operator’s organization. A safety management system intends to move the company from a reactive to a proactive generative safety culture so as to identify hazards before they can happen.

As mentioned in the previous section, FOQA, LOSA, and ASAP are among the most relevant programs that underlie the aviation safety proactive approach. FOQA entails taking quantitative flight data from routine operations and using them to detect hidden hazards. The concept involves the study of routine flight data to enable early intervention to correct adverse safety trends before they lead to accidents. The method also provides an objective means for validating the effectiveness of corrective actions after they are implemented (Stolzer et al., 2008; Cusick et al., 2017).

The LOSA (also called an assessment versus an audit) describes a voluntary and formal process that uses highly trained observers to collect safety-related data on regularly scheduled flights. It involves a flight observer (usually a trusted airline captain) who stays in the cockpit to annotate data about flight crew behavior. He also aims to assess crew strategy for managing threats and errors under conditions of operational complexity. These threats and errors are part of everyday operations that crew members must handle to maintain flight safety (Stolzer et al., 2008; Cusick et al., 2017).

Another fundamental program is the ASAP based on spontaneous reporting. This program is a voluntary and confidential reporting system for pilots and other aviation professionals for sharing close calls in the interest of improving air safety. ASAP helps address the reasons why one is approaching the limits of safe operations so that measures can be taken before accidents happen (Stolzer et al., 2008; Cusick et al., 2017).

As a scientific approach to managing safety, the primary goal of SMS is to institutionalize the processes for safety decision making throughout an organization that relies on managing safety through measurement. In fact, SMS aims at the continuous improvement of the overall level of safety while measuring performance, scrutinizing processes, and becoming an integral part of the company's business management and organizational culture. Hence, the implementation of an SMS requires methods that allow the control of safety risks and introduces the concept of the acceptable level of safety (Muller et al., 2014; Cusick et al., 2017).

Although many companies and operators already use a form of safety management, this is often a long way from being designed effectively. Often operators restrict themselves to risks on the operational level, or risk management is considered only as prevention management. Risk management has to cover all organization areas and has to be communicated across all business functions to be effective. Many aviation companies have excellent safety records while still operating with risky behavior characteristics or inadequate organizational structures. They have just not had an accident yet. However, an exemplary safety record does not guarantee future safety — a fact that various aviation stakeholders haven't clearly understood yet. Safety does not happen by chance (Muller et al., 2014).

2.4.2.3 The Production/Protection Dilemma

Because there are hazards in aviation, a consequence of production (e.g., providing air transportation) is a safety risk. This risk requires a protection system for users and stakeholders, which is a commitment of the aviation service provider (most directly) and the regulating authorities. This protection system is essentially what an SMS should deliver. The management of an organization must balance the production and protection objectives. More often than not, this balance is fragile - too much production may jeopardize the safety, and too much safety may compromise financial performance (Stolzer et al., 2008).

Reason (1997) argued that the partnership between production and protection is seldom equal, with one of them predominating over the other, depending on the current situation. Since production generates the resources that make protection possible, its needs will usually have priority during most of a company’s lifetime. Two reasons explain that mindset. First, the company's managers possess productive rather than protective skills. And second, the information relating to production is direct, continuous, and promptly understood.

On the other hand, strong protection is indicated by the absence of adverse outcomes. The associated information is indirect and irregular. The measures involved are difficult to interpret and often misleading. It is only after an unfortunate accident or a frightening near-miss that protection comes - for a short period - highest in the minds of the company's top leaders (Reason, 1997).

The allocation of disproportionate resources to protection or risk controls may result in the product or service becoming unprofitable, thus endangering the viability of the organization. On the other hand, excess allocation of resources for production at the expense of protection can harm the safety performance of the product or service and can eventually lead to an accident. Therefore, it is vital that a safety boundary be defined that provides an early warning that an unbalanced allocation of resources exists or is emerging. Figure 18 summarizes these concepts by showing James Reason’s Safety Space. (ICAO, 2013).

One of the main purposes of an SMS is to improve safety performance, and thus reduce exposure to the risk of having an accident or suffering bankruptcy. The implementation of a safety management system should lead to an overall improvement of the processes of a company and should contribute to commercial aviation's fundamental business goals: to enhance safety performance, aim at best practices, and comply with regulatory requirements (Muller et al., 2014).

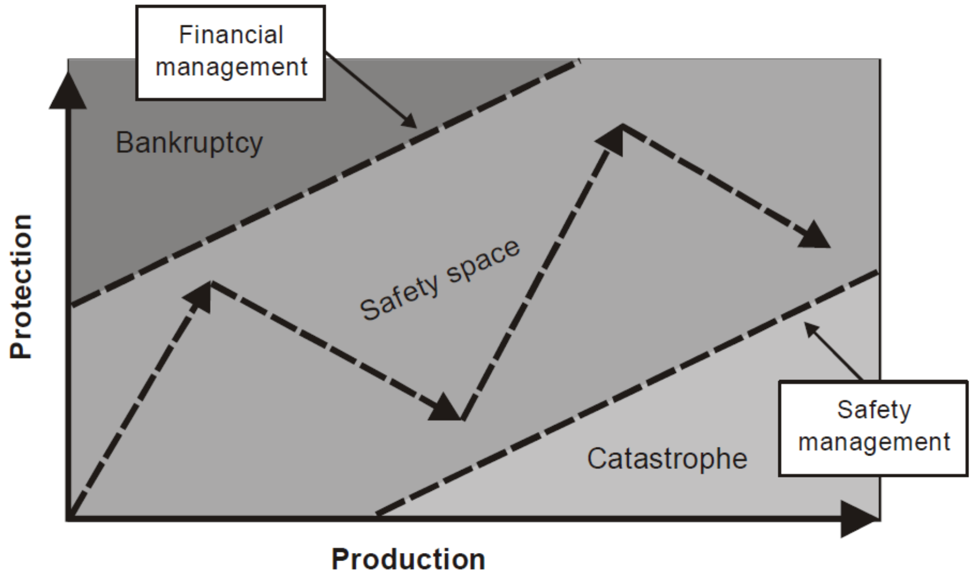

Figure 18. James Reason's Safety Space. Note. Adapted from ICAO, 2013.

With the help of SMS, companies and operators can examine and make decisions about their operations. From their analysis, they can promptly adapt to change, using quantitative methods to support efficient management through measurement of key performance indicators. SMS heavily promotes the continuous development of safety through data collection and analysis that provides valuable employee feedback. By doing this, SMS can greatly enhance the safety culture across the organization (Cusick et al., 2017).

In their research, Remawi et al. (2011) observed that while SMS may be necessary to achieve consistent results, they often do not, in isolation, prevent workplace safety incidents and accidents from occurring. The influence and importance of workplace safety culture in affecting safety outcomes must also be considered. The study suggests that the implementation of an SMP into an organization results in an improvement in the measure of the safety culture at that organization.

Therefore, establishing a safety culture is one of the most challenging elements of an SMS. Creating a safety culture begins at the top level of an organization, with the incorporation of policies and procedures. The organization must cultivate the willingness of its members to report errors in order to support its safety culture. Companies and operators have to commit not to punish errors, as long as they are not reckless. Then the analysis of those important reports becomes valuable sources in the context of hazard identification and, more importantly, builds the foundation for an effective SMS. (Muller et al., 2014).

2.4.3 Fatigue Control System

2.4.3.1 Fatigue Risk Management Systems

Hollnagel et al. (2011) argue that human fatigue is today regarded as one of the most significant risks for safety in many industries, especially in aviation. The prescriptive approach through the regulation of duty hours is the traditional way to prevent fatigue. However, besides the inherent rigidity of rules from an operational standpoint, this often falls short of taking into account all of the complex dimensions of fatigue. The aviation industry has been progressively applying FRMS so as to handle that complexity. FRMS approach evaluates each operation in terms of fatigue risk, instead of just setting absolute duty time limitations. FRMS is a concrete way to engineer resilience because it requires the organization to adjust its functioning by re-introducing safety managed by experts in addition to safety by regulations.

FRMS is a data-driven means of continuously monitoring and mitigating fatigue-related safety risks, based on scientific principles, knowledge, and operational experience that intends to ensure essential personnel are performing at adequate levels of alertness. The FRMS approach represents an opportunity for companies to use advances in scientific knowledge to improve safety, use resources more efficiently, and enhance operational flexibility. An FRMS offers a way to more safely conduct flights beyond existing regulatory limits and should be considered an acceptable alternative to determined flight and duty time and rest period regulations (Caldwell et al., 2009; ICAO, 2016).

According to ICAO (2016), having an FRMS still requires holding maximum duty times and minimum non-work periods, although the Service Provider may propose them. If these limits differ from the prescribed limits, they must be approved by the State. To get approval, the service provider must demonstrate to the regulator that it has appropriate processes and mitigations to achieve an acceptable level of risk.

Caldwell et al. (2009) call attention to the fact that each type of aviation operation has its complexity, whether it be working extended duty days, crossing time zones, or sleeping at adverse circadian times. These physiologically important factors are unique to each schedule. They are also affected by specific organizational needs and airport operating requirements. The combination of these factors requires a new approach that addresses operations on an individual case basis and also allows for operational flexibility. An FRMS approach will enable companies to address both physiological and operational factors. An FRMS program consistently contributes to ensuring that performance and safety levels are not compromised, by offering an interactive way to safely program and conduct flight operations on a case-by-case basis.

As the FRMS is intended to be an integrated part of the SMS, the FRMS has been structured around the four essential components of the SMS - safety policy and objectives, safety risk management, safety assurance, and safety promotion. When designing an FRMS, safety specialists should conceive policies and procedures that focus on the company’s specific type of operations. There should be a commitment from leaders to mitigate fatigue and improve flight crew alertness due to its direct impact on safety (Hollnagel et al., 2011; ICAO, 2013; Cusick et al., 2017).

An FRMS also encourages an organization to design education awareness training programs for fatigue. Content should include the basics of fatigue, effects of operating with the condition, and countermeasures, prevention, and mitigation. Furthermore, there should be an incident reporting process to help prevent performance errors attributed to fatigue. In this context, a safety culture plays a crucial role in aviation safety by engaging everyone in the company to act as a defense against the negative consequences of operating with fatigue. Figure 3 shows how FRMS interacts with the fundamentals of SMS (Hollnagel et al., 2011; ICAO, 2013; Cusick et al., 2017).

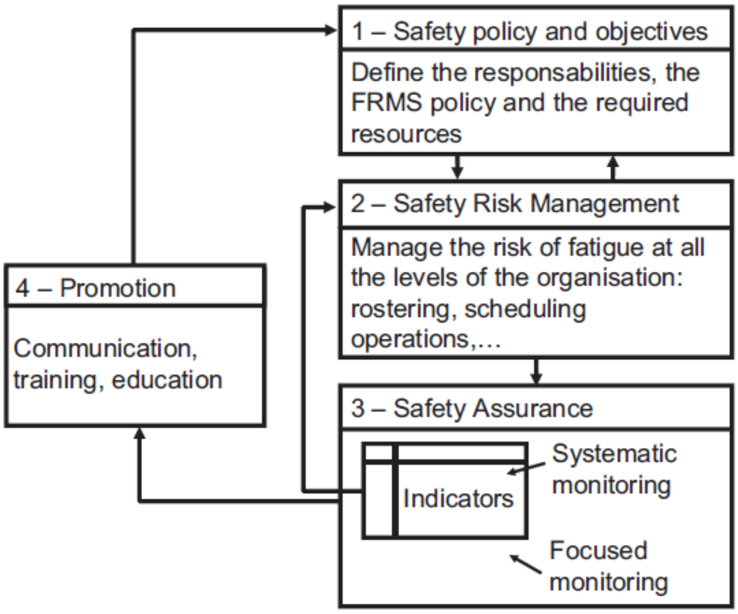

Figure 19. The whole Fatigue Risk Management System. Note. Adapted from Hollnagel et al., 2011.

That is why implementing a formal fatigue management program demonstrates that the risks resulting from sleepy personnel are known, and the organization is actively mitigating these risks both on and off the job. In an effective FRMS, essential procedures to reduce fatigue are integrated into an overall SMS program that guarantees that employees get sufficient sleep and are monitored for fatigue-related issues; controls are in place to minimize the impact of fatigue-related errors; and fatigue-related procedures are periodically assessed to ensure their effectiveness (Caldwell et al., 2019).

2.4.3.2 Fatigue Countermeasures

Considering the pace of modern society and economic realities, including work, family, and travel demands, complete elimination of fatigue is an unrealistic goal. People are diurnal organisms who are, by their innate nature, poorly prepared for long periods of continuous wakefulness, nighttime work, and significant changes in sleep/wake schedules. Due to the scope of the fatigue problem, a considerable amount of research has examined the effectiveness of various interventions that might reduce fatigue effects on the flight crew. These interventions are referred to as fatigue countermeasures (Driskell & Mullen, 2005; Caldwell et al. 2019).

We should bear in mind that the main fatigue countermeasure is education. It is critical that personnel learn about the dangers of fatigue, the importance of obtaining adequate sleep, understanding that full recovery from fatigue may take longer than anticipated, and the fact that healthy sleep habits are essential for ensuring optimal sleep quality.

Educating employees about fatigue-related work and social/familial hazards, circadian rhythms, and lifestyle factors in the fatigue equation; and treatment for sleep disorders can steadily contribute to aviation safety. Nonetheless, managers must assume a key role in not only supplying information but also in providing the motivation and the necessary resources for employees to come to work in a well-rested state (Caldwell et al., 2009; Caldwell et al., 2019).

Another critical point is optimizing sleep opportunities. The most significant cause of fatigue in the workplace is insufficient or disrupted off-duty sleep. Of course, some sleep issues are inevitable, but others are manageable to modification, especially with the use of a well-planned sleep strategy. Obtaining the required quantity of sleep on a day-to-day basis is essential, but getting high-quality sleep is beneficial as well. For situations in which sleep opportunities are available, it is vital to ensure employees take the most advantage of them to recover from the effects of prior wakefulness and prepare for the next duty period. When appropriate, the use of sleep medications should be considered, but when pharmacological solutions are not indicated, behavioral sleep-optimization strategies, such as meditation, can be a helpful alternative (Caldwell et al., 2009; Caldwell et al., 2019).

Naps and sleep inertia are also hotly debated topics in safety. Although there is general agreement that naps may be a useful fatigue countermeasure, there is less consensus on how naps should be managed as an effective operational strategy. On the one hand, a nap during long periods of continuous wakefulness can significantly improve alertness and performance. On the other hand, Sleep inertia may be a serious concern when napping is proposed as a fatigue countermeasure, especially if skilled performance is required immediately after the nap. However, this short-term disadvantage must be wisely balanced against performance degradation from sleep deprivation (Driskell & Mullen, 2005; Caldwell et al. 2019).

The identification and treatment of sleep disorders are often neglected as an effective counter-fatigue strategy for the workplace. However, any condition that disrupts normal restorative sleep is likely to harm workplace performance unless it is recognized and mitigated by the organization (Caldwell et al., 2019).

Ensuring that employees and supervisors are able to rapidly recognize signs of excessive fatigue and procedures for actions to immediately mitigate either fatigue itself or the risks due to fatigue can make huge strides in improving safety. Effective measures may include switching the employee to a less-safety-sensitive role, augmenting peer-based cross-checking procedures, using caffeine to increase alertness temporarily, or changing the type or intensity of environmental lighting (Caldwell et al., 2009; Caldwell et al., 2019).

Shift schedules are another crucial fatigue countermeasure. Working non-traditional shifts either on a fixed or rotating basis adversely affect employees' cognitive performance. It is challenging to manage sleep and, consequently, fatigue under these circumstances, but adequate shiftwork scheduling is quite helpful. Managers should ensure sufficient staffing levels and workload balance to reduce fatigue-related problems associated with shift work. A shiftwork-scheduling guide should be consulted before establishing work schedules, and when possible, an assessment of fatigue risk and sleep impact should be conducted using biomathematical modeling and recordings of wrist actigraphy (this topic is discussed in the next section) (Caldwell et al., 2019).

Finally, all fatigue countermeasures must be supervised by psychologists and physicians. Active psychological and medical surveillance is fundamental to ensure that operators are in good health and able to carry out their job without excessive stress and performance impairment. Hence, checks have to be focused mainly on sleeping habits and troubles, eating and digestive problems, mood disorders, psychosomatic complaints, drug consumption, workload, and off-job activities, preferably using standardized questionnaires, as well as checklists and rating scales, to monitor the worker's behavior. Moreover, permanent education and counseling should be provided for improving self-care strategies for coping, in particular, concerning sleep, diet, stress management, physical fitness, and medications (Wise et al., 2010)

2.4.3.3 New Technologies

Real-time fatigue monitoring technologies and fitness-for-duty testing devices have been investigated for many years with limited success. However, there is a potential benefit for fatigue-detection technologies that identify fatigued workers and notify their organization, or the workers themselves, when a fatigue-related risk has reached an unacceptable level. These technologies are typically designed to detect behavioral indicators of fatigue. Several technologies are already in use in the transport, health, and mining industries. Devices may be based on neurobehavioral and physiological correlates of fatigue (e.g., reaction time or frequency, duration and rate of eye closures), or embedded performance measures (e.g., vehicle dynamics such as variability in velocity or steering lane position). While fatigue detection devices may often be marketed as practical solutions for mitigating fatigue-related risk, there is currently little systematic evidence regarding their scientific reliability or validity or legal defensibility. There are no current regulatory guidelines regarding the appropriate use of these technologies and how they contribute to the effectiveness of an FRMS (Dawson et al., 2014).

Based on the validation evidence available, none of the current technologies met all the proposed regulatory criteria for a legally and scientifically defensible device. Further, none were sufficiently well validated to provide a comprehensive solution to managing fatigue-related risk at the individual level in real-time. Nevertheless, several of the technologies may be considered a potentially useful element of a broader fatigue risk management system. A proven alternative for assessing basic sleep parameters in such circumstances is wrist-worn sleep/activity monitoring. Continuous sleep/wake measurement derived from actigraphy can form the basis of a fitness-for-duty program since it can determine whether or not individuals are obtaining the 7–8 h of sleep generally required for adequate rest and restoration (Dawson et al., 2014; Caldwell et al., 2019).

Biomathematical models, in association with actigraphy, can predict the risk of fatigue associated with specific patterns of working hours. Several software tools have been developed that might be usable for the design of a new roster after the introduction of a new route or as a result of a significant change of schedule. These models use structural equations models to predict fatigue levels based on factors including recent sleep quantity, sleep quality, sleep/wake timing, the current time of the day (during duty), and workload. Safety experts can reduce schedule-related fatigue incidents and accidents by applying biomathematical models to help identify the risks associated with specific work/rest schedules, guide the implementation of fatigue countermeasures, help in accident investigations, and reinforce counter-fatigue educational efforts (Hollnagel et al. 2011; Caldwell et al., 2019).

In their research study, Van Drongelen et al. (2013) suggest that prolonged fatigue causes many health problems, impairs performance capability, and disturbs work-private life balance among flight crew. Based on these findings, they propose that several measures counter the adverse effects of fatigue be translated into practical advice to flight crew through mobile devices. Those pieces of advice are evidence-based and aim to optimize the pilots' behavior concerning exposure to daylight, sleep (sleep behavior and timing of rest), nutrition, and physical activity. The specific words of advice should be tailored to the flight crew, depending on flight direction, flight duration, and the number of time zones crossed, for instance. This implies that the advice differs per destination and person and that the total number of different advice messages is high.

Furthermore, due to this complexity, translating the theoretical knowledge into training programs for flight crew has proven to be difficult. Therefore, to improve adherence, these interventions should be designed to allow individuals to tailor it to their own specific needs. The development of an intervention consisting of a set of tailored advice (about daylight exposure, sleep, physical activity, and nutrition) delivered through a smartphone application for airline pilots, and the design of a randomized controlled trial evaluating its effect on fatigue, health and sickness absence can contribute to FRMS. In fact, offering tailored advice through a mobile Health intervention is an effective means to support employees who have to cope with irregular flight schedules and circadian disruption (Van Drongelen et al., 2013).

2.4.4 Mitigating Risks

2.4.4.1 New Challenges and the Law of Unintended Consequences

Since 2004, the accident rate has been relatively constant, with no significant improvement, averaging between four and five fatal accidents per 10 million flights. This could be because aviation safety has reached a level at which safety benefits balance its costs. However, increasing deregulation and competition, as well as the expected increase in air traffic over the next decades, may put current safety levels into jeopardy (Insua et al., 2018).

The total elimination of aviation accidents and serious incidents is a desirable goal, but patently unachievable. The idea of risk-free systems has evolved in recent years towards a perspective focus on safety management, aimed at supporting the resource allocation process in which a balance between "production" and "protection" is achieved (Insua et al., 2018).

In reality, improving safety is hypothetical, with usually no hard evidence to justify initiatives, particularly when the ideas are based on non-accident data. The result is that it is often a difficult task to convince others of the monetary trade-off needed to implement a safety improvement (Cusick et al., 2017).

According to Muller et al. (2014), risks are considered as an essential element of strategic management and are discussed in many empirical industry studies and are prominent in connection with firm and business unit performance. Risk management is generally understood as the holistic process involved in recognizing possible risks and the measures undertaken to reduce and monitor them. Therefore, it includes a modular cycle of communication, documentation, control, early warning mechanisms, and advancement.

Especially in times of crisis, the strategic importance of risk management becomes quite clear. The massive increase in forecast uncertainty leads to a competitive advantage for companies that can interpret and manage risks better than others. Since companies are usually only able to achieve higher returns by simultaneously taking additional risks, risk management, in particular, has to decide what kinds of risks are acceptable for the company (Muller et al., 2014).

One key aspect that safety managers must consider before attempting to solve any particular problem, including the balance between production and protection, is the so-called “law of unintended consequences.” Although every initiative must be assessed for potentially adverse outcomes before operations are changed, in many situations, well-intentioned actions have dangerous effects that were not previously anticipated. In essence, such a case removes one risk but possibly replaces it with an even higher risk for the organization (Cusick et al., 2017). When it comes to the employment of brand-new technologies, the law of unintended consequences is particularly relevant. Each new generation of technology offers some solutions to the problems that existed in the older generation while creating a whole new set of problems. Dekker (2002) added an important element to this discussion by arguing that the aerospace industry had seen the introduction of more state-of-the-art technology as an illusory medicine to human error. In fact, in many circumstances, instead of reducing human error, technology not only changed it, but it also aggravated the consequences and delayed opportunities for error detection and recovery within the organization (Martinussen & Hunter, 2017).

2.4.4.2 Risk Assessment

Over the last ten years, we have witnessed some initiatives to integrate management knowledge with risk assessment, such as the International Organization for Standardization (ISO) 31000:2009 and 31000:2018 - Risk Management Principles and Guidelines. Those guidelines are the available worldwide standard for risk management. The purpose of that ISO 31000 series is to integrate and adapt the risk management process to already available management systems, in order to optimize and tailor the risk management process to the needs of organizations and not to fulfill compliance issues (Muller et al., 2014; ISO, 2018).

In this regard, it is worth mentioning that one of the most popular methods for risk management in aviation safety is based on risk matrices. A risk matrix is a tool for risk assessment and management that graphically represents the severity and likelihood of different risk factors. The most relevant regulatory organizations, such as the ICAO, the EASA, the FAA or the EUROCONTROL, support and promote their use in all aviation sectors, from airports to air traffic control in the incumbent country (Insua et al., 2018).

Aviation companies have been taking advantage of two of the most recent and widespread expressions for managing error in flight operations - CRM and TEM. Both tools rely heavily on using the positive synergy of teamwork so as to mitigate operational risks. Moreover, safety professionals have been using safety performance indicators (SPIs) to get a quantitative feel for how healthy the safety of their operation is at any given time, to measure whether safety is improving or deteriorating, and to compare safety in different segments of a given operation. When properly designed and measured, SPIs can provide the following data:

• Early warnings that a serious incident or accident may be imminent,

• How often preset limits are violated or how often they are almost exceeded,

• How willing are employees to complete and submit voluntary safety reports,

• The frequency with which specific events are occurring,

• The effectiveness of new strategies and policies; and

• Different benchmarks for current practices to measure future initiatives (Cusick et al., 2017).

Finally, operational risk management (ORM) deals with the risk of loss resulting from inadequate or failed internal processes, people, and systems or external events. ORM and line management together assess and monitor these risks and prepare risk mitigating strategies and actions. In order to have a response ready to react to a subset of operational risks, defined by the scope and size of events, companies devise their business continuity plan. The focus of business continuity management is not on risks to the core business objectives, but on external threats that lie outside the competencies of the business and cause significant disruption that might threaten the survival of the company (Muller et al., 2014).

3 METHODOLOGY

This section presents the research methodology employed in the proposed study. The type of research, universe, sample, and interviewee selection are also described. Moreover, data collection and analysis are presented. Finally, limitations of the method are discussed at the end of the chapter.

3.1 Type of Research

According to Flick (2009), qualitative research is particularly relevant to the study of social relations, due to the fact of the pluralization of lifeworlds. That diversification, along with rapid social changes, is increasingly confronting social researchers with new social contexts and perspectives. The recognition and analysis of different angles and the researchers' reflections on their research as part of the process of knowledge production are essential features of qualitative research. What’s more, Belk et al. (2013) consider that it is normal for qualitative researchers to try to observe and interact with people in the contexts that shape their everyday behaviors and perceptions.

Creswell (2013a) argues that qualitative research is an approach for exploring and understanding the meaning individuals or groups attribute to a social or human problem. This process of research involves emerging questions and procedures, data collected in the participant’s setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data. This approach focuses on individual purpose and the importance of rendering the complexity of a situation.

Vergara (2005) points out that a research study can be classified according to its purpose or means of investigation. The classification by purpose identifies research study as exploratory, descriptive, explanatory, methodological, applied, or interventionist. In this classification system, an exploratory study is performed in areas of little systematized knowledge. Therefore, it does not involve assumptions in the early stages, although they may arise as a result of the investigation.

In this research study, a qualitative approach was chosen because it fits the research questions properly and offers an adequate way to construct the required knowledge. As mentioned in section 1.2, the research questions are:

a) What are the main human factors that affect pilots' safety behavior in offshore operations?

b) How can offshore aviation companies manage to mitigate the adverse impacts of those human factors on their pilots' safety behavior?

The fact that, in Brazil, little research has been carried out on offshore aviation safety and its complexity indicate that a qualitative approach is recommended for this research study. This exploratory study aims to better understand human factors in aviation and, more specifically, their impact on the safety behavior of helicopter pilots in the context of the three main companies operating in the Brazilian offshore sector.

According to Stake (2010), in a qualitative study, the researcher himself is an instrument, observing action and contexts, often intentionally playing a subjective role in the study, using his personal experience in making interpretations. Moreover, qualitative research is subjective and personalistic. Observation, interviewing, and examination of artifacts (including documents) are the most common methods of qualitative research. In this study, the researcher, a helicopter pilot himself, used his previous experience in operating in the offshore sector to better assess and interpret the most relevant human factors from the interviewees' perspective.

Qualitative research draws heavily on interpreting by researchers—and also on understanding by the people they study and by the readers of the research reports. Qualitative description of how things work relies heavily on personal experience. The researcher usually has face-to-face encounters with the activity. Interviews are arranged to learn more about the experience of the participants (Stake, 2010). That is why, in this paper, interview data, open-ended questions, and observation data (Creswell, 2013a) were applied as qualitative research methods. A comprehensive and in-depth analysis was carried out in order to better comprehend a contemporary issue of the offshore aviation sector in Brazil.

3.2 Universe, Sample and Interviewee Selection

According to Vergara (2005), the research universe represents the entire population and the sample population, that is, all the set of elements (e.g., individuals or organizations) that have the necessary characteristics to be an object of study. The sample is a part of this universe, chosen according to specific representativeness criteria. All pilots interviewed in this research study worked for one of the three leading helicopter transportation service companies in the sector. Those three companies alone represent in terms of number of aircraft more than 85% of the offshore aviation industry in Brazil.

This exploratory study looks into the scenario of a small economic recovery through which the offshore aviation sector has been going over the last year after a considerable drop in the number of business contracts between 2014 and 2017. This crisis imposed significant challenges to offshore aviation companies concerning training programs, compensation programs, operational schedules, and layoffs.

Companies' pilots have different backgrounds (e.g., retired military officers, former employees of other offshore aviation companies), and levels of experience in aviation (flight hours in general) and in the sector (years of experience and flight hours in offshore operations). Moreover, they can perform two different functions in the cockpit of a specific aircraft; they can be either a commander or a copilot.

According to Ritchie & Lewis (2003), qualitative researchers usually employ non-probability samples for selecting the population for their studies. In a non-probability sample, units are deliberately chosen to reflect particular features of or groups within the sampled population. In this study, in order to dive into which human factors pilots of different levels of expertise and experience perceived as the most relevant to their safety, 16 helicopter pilots were selected in a non-probability way for the interviews. Table 1 shows further information about the interviewees. Some criteria were taken into account in that selection, such as willingness to participate, availability, the type of aircraft flown, practical knowledge, dexterousness, to name a few. Needless to say, interviewees' names were not included in table 1 for the sake of guaranteeing their anonymity.

3.3 Collection and Analysis of the Data

In the present case study, data collection was conducted by 16 in-depth, individual, semi-structured, and in-person interviews using an interview guide previously conceived (Table 1). As a data collection method, in-depth interviews provide an opportunity for a detailed investigation of each person's perspective. Very complex systems, processes, or experiences are generally best addressed in in-depth interviews because of the depth of focus on the individual and the opportunity for clarification and detailed understanding (Ritchie & Lewis, 2003).

Table 1 – Interviewees' Characteristics

INTERVIEWEE	POSITION	AGE GROUP	RANGE OF YEARS OF EXPERIENCE - OFFSHORE AVIATION SECTOR	FLIGHT HOURS (total / in the sector)	AIRCRAFT FLOWN
Interviewee 1	Commander	45 - 50	15 - 20	11,000 / 10,000	S-76 and S-92
Interviewee 2	Copilot	50 - 55	5 - 10	5,000 / 3,000	AW-139 and AW-155
Interviewee 3	Copilot	50 - 55	0 - 5	2,500 / 500	EC-225
Interviewee 4	Commander	60 - 65	15 - 20	10,000 / 7,000	S-76, EC-225, EC-135, EC-155 and S-92
Interviewee 5	Copilot	50 - 55	0 - 5	3,000 / 1,000	S-76
Interviewee 6	Commander	35 - 40	15 - 20	8,000 / 7,500	S-76 and S-92
Interviewee 7	Copilot	50 - 55	5 - 10	5,000 / 2,000	AW-139 and EC-155
Interviewee 8	Commander	40 - 45	20 - 25	10,500 / 10,000	S-76, EC-332, EC-225 and S-92
Interviewee 9	Commander	50 - 55	10 - 15	8,500 / 7,500	Bell-222, S-76, AW-139 and AW-189
Interviewee 10	Copilot	45 - 50	5 - 10	6,500 / 2,000	S-76, EC-225 and S-92
Interviewee 11	Copilot	35 - 40	5 - 10	2,500 / 2,000	S-76
Interviewee 12	Commander	50 - 55	20 - 25	15,500 / 15,000	S-76, EC-225 and S-92
Interviewee 13	Copilot	50 - 55	5 - 10	3,000 / 500	EC-135 and EC-155
Interviewee 14	Commander	30 - 35	10 - 15	5,000 / 4,500	Bell-212, EC-135, EC-225, S-92 and AW-139
Interviewee 15	Copilot	50 - 55	5 - 10	7,000 / 2,500	S-76, AW-139 and AW-189
Interviewee 16	Copilot	30 - 35	0 - 5	2,000 / 1,000	S-76

The interview script (appendix 1) was conceived, taking into consideration the human factors that were more relevant to aviation, in particular to offshore and helicopter operations, according to the literature review. It was composed of 58 questions, including open-ended ones, and was written in Portuguese, since all interviewees are native Portuguese speakers. The questions covered mainly the interviewees' perception of work and safety. The interview script was handy to help the researcher stay focused on the objectives of the study. It served as a guide and suffered necessary changes in the course of each interview, depending on the content that had emerged during the interaction. This is a fundamental aspect of this study since in qualitative research researchers empower individuals to share their stories and their perceptions and even encourage them to collaborate with the investigation by helping review the questions and interpret some data (Creswell, 2013b). Each interview lasted 1 hour and 45 minutes on average.

Furthermore, the participants were also asked about their experiences with the safety tools and systems to explore how the adverse impacts of human factors on pilots' safety behavior may be mitigated. The questions were devised to make the interviewee comfortable to answer them. At the beginning of each interview, interviewees were assured of the anonymity of the process and their right to not answer any question if they don't want to. All interviews were recorded with the consent of the respondents and then transcribed by the researcher.

It is worth mentioning that, in order to protect interviewees' anonymity, the information provided in table 1 was adapted and presented in broader terms, such as age groups and range of years of experience. Moreover, other sensitive personal characteristics, such as gender, that might help identify some of the interviewees, were omitted.

Finally, the interviews were conducted in the cities of Rio de Janeiro, Cabo Frio, and Macaé during the months of April, May, and June of 2019. The meetings were previously scheduled based on the availability of the respondents.

This research study employs discourse analysis to identify categories that represent the key themes of interest in the interviews. In other words, the transcription of the 16 in-depth interviews was carefully analyzed to develop categories that reflect the most relevant topics in the samples for investigation. Therefore, those categories were the guidelines for the entire analysis process.

3.4 Limitations of the Method

First, we need to take into account that the analysis of a small sample of offshore pilots may have presented different aspects of the human factors if the interviews had been conducted with a larger sample. The sample, therefore, cannot be considered to represent the entire sector. Furthermore, since this research study addresses a specific case, its results cannot be generalized concerning the offshore aviation sector or the aviation industry. We should also bear in mind that, concerning data analysis, since a qualitative method was applied, the researcher's interpretation has a strong influence on the results of the work.

4 RESULTS

This section presents the assessment of the collected data from 16 in-depth interviews with helicopter pilots presently working for the three main companies that operate with offshore flights. Initially, the Brazilian offshore aviation sector analysis, from the respondents' perspective, is briefly introduced. Then, the main categories that emerged from the interviews are discussed. Passages from the interviews' transcripts are quoted so as to illustrate the discussion.

4.1 Panorama of the Brazilian Offshore Aviation Sector

In Brazil, the offshore aviation sector has consistently improved in terms of flight safety over the last 20 years. Almost all national offshore aviation companies have partnered with international operators with extensive experience in the industry. Those companies started to bring the best practices concerning aviation safety from more developed offshore areas such as the North Sea and Norway. What's more, the Brazilian oil and gas company, i.e., the main contractor (hereby referred to as MC), has outsourced consulting firms to highlight the main problems of offshore aviation in order to develop the sector. In their first reports, they presented the risks of operating old aircraft (30 years old) for 8 hours a day for offshore flights.

> "When I began to fly for my first offshore company 18 years ago, mechanical or electric failures were recurrent, and the availability of the aircraft was deficient. This happened because we were flying very old helicopters for many hours a day. Fortunately, in 2004, we started to receive cutting-edge helicopters. Moreover, we shifted from an average of 7 to 8 flight hours per day of operation to an average of 5 to 6 hours". (I01).
>
> "The market requirements established by the ANAC and the MC regarding the qualifications of the pilots are well structured. Operation now is much safer than it was when I started to fly in the sector 22 years ago. Aspects that were previously ignored, such as weight and balancing, are now considered of the utmost importance". (I12).

As of 2014, the oil and gas sector started to face a serious economic and ethical crisis. There were far-reaching and severe consequences for helicopter transport service companies. The number of contracts with oil and gas companies, especially with the leader of the market – MC, has considerably reduced, leading aviation companies to diminish the number of aircraft operating in the offshore sector and to lay off many highly qualified pilots. As a result, the profit margin of offshore aviation companies has plummeted, and contracts are now shorter (only two years) than they were before the crisis (five years).

> "At the end of 2014, MC reduced production and started returning various platforms to their home countries (Norway and China). As a result, the contracts with the offshore aviation companies were closed and not renewed, negatively affecting the sector". (I03).
>
> "In 2015, the crisis of MC happened as a result of Operation *Car Wash*. There have been many layoffs since then. There were 287 pilots in my company in 2014. In 2015 only, we had to make redundant 91 pilots. Of 52 helicopters under contract, we moved to only 41". (I09).
>
> "Currently, there are approximately 90 aircraft flying in the industry. There were 120 in 2013 before the crisis. I estimate that, in the medium term, we will again have 120 aircraft in offshore aviation. I also estimate that today there are about 250 unemployed pilots ready for offshore aviation". (I15).

According to many interviewees, the main obstacle to the development of the sector is the lack of credibility of the country and the offshore industry. Corruption in the sector significantly undermined its credibility with society, driving serious investors away. That is why many foreign oil and gas companies are reluctant to invest heavily in the oil industry in Brazil. Therefore, MC remains the main helicopter transport service contractor (80 to 90% of all contracts are signed with the giant Brazilian oil company). This lack of competition has led to certain distortions within the sector. Furthermore, there are too few offshore aviation companies as well (three big ones and a couple of smaller ones). In fact, the thee leading helicopter transportation service companies, for which all the pilots interviewed in this research worked, account for more than 85% of the entire sector.

> "The three main offshore aviation companies constitute more than 85% of the whole sector." (I01).
>
> "The offshore aviation sector is too concentrated – the three leading companies are equal to more than 85%. Moreover, the biggest obstacle to the growth of the sector is the country's political and economic instability." (I14).
>
> "The lack of competitiveness is the major obstacle to offshore aviation in Brazil. There is practically only one contracting company." (I16).

Many interviewees think that offshore aviation companies should be more assertive about their positions, especially concerning aviation safety and standardization of flight procedures. In fact, the contractor ends up interfering in the internal affairs of the companies, since it has enormous power over them. Therefore, more competition within the oil and gas industry would really be beneficial to helicopter transportation service companies.

> “The profit margins of the sector are minimal. Thus, aviation companies, afraid of losing market share, end up giving in to certain demands of the contractor. This has a direct impact on flight safety. In reality, MC charges a lot and collaborates little. Foreign O&G companies have a more collaborative and less authoritarian stance.” (I09).

> “The monopoly of MC is the main obstacle for the development of the sector. Oil production depends fundamentally on the air transportation of the workers to the oil rigs. In this sense, aviation companies could positively influence MC in order to establish the conditions for a safe and economically viable air transportation service. That monopoly has led to a price war, excessive workload, personnel with qualification gaps, and huge pressure on pilots and mechanics.” (I04).

> “The main obstacle today is the great influence that MC exerts in the sector, establishing controversial rules, often without any technical support." (I15).

Offshore aviation is totally dependent on the contracts signed with the client companies. Thus, companies only hire the exact number of pilots required per contract. Since there is a vast availability of highly qualified unemployed pilots in the market, aviation companies do not bother to keep a safe number of pilots as a strategic human resource reserve.

The shrinkage of the sector and the massive layoffs have provoked an epidemic fear of unemployment among offshore pilots. The number of unemployed skilled pilots has achieved alarming levels. This panic, coupled with a profession that lacks a cohesive organization (the union of the pilots is not very active), led the pilots to accept less favorable working conditions and lower compensation packages.

> “Between 2012 and 2015, there was a huge demand for pilots. Unfortunately, at this time, pilots did not organize themselves as a strong category. In reality, the union has never had much power, especially when it comes to negotiating wage raises. With the economic crisis and because the category lacks unity, companies have started to fire pilots and to reduce wages and working conditions. Had the pilots organized themselves properly during the period of expansion of the sector, the working conditions would be much better now.” (I07).

> “There is no tolerance for minor mistakes. Everything can cause you to get fired. Since aviation companies are very submissive to the main contractor, any event out of normality will lead them to want the *pilot's head*. This causes insecurity and stress among us, especially in the cockpit.” (I04).

> “The fear of dismissal has negatively influenced the performance of pilots who now are much more uptight and worried during their flights." (I05).

Finally, when it comes to the prospects of the sector, there is no consensus among pilots whether or not it will recover from the crisis in the years to come. Pilots are not very upbeat about the future of offshore aviation.

> “A few years ago, it was expected that in 2019 the market would experience a new boom due to the arrival of other foreign companies that would contract the services of the offshore aviation companies. My perception is that this will not happen. The market improvement is still very slow and small.” (I09).

> “The worst period of the crisis is already over. There is a small growth in the sector.” (I12).

> “What is necessary for the sector to thrive is an economical and politically stable environment where foreign investors can trust in Brazilian institutions." (I13).

4.2 Categories of Analysis

Along with the interviews' transcription, ten elements were identified as the main factors that affect the behavior of offshore pilots, namely organizational culture, communication, and power distance, standardization and subjectivity, motivation and fear of unemployment, stress, fatigue, human error, pilot and position selection, safety management system, and perceived loss of prestige. Hence, these topics guided the analysis presented in this section.

4.2.1 Organizational Culture

In order to tackle the Brazilian economic crisis, offshore aviation companies had to prioritize the financial aspect of their operations, which has increased the pressure on pilots. Some pilots argue that the monopoly of a contracting company generates questionable operational requirements, originated from commercial aviation, that are not adequately adapted to the peculiarities of helicopter aviation in a predominantly maritime environment.

Due to the fear of being made redundant, pilots are more insecure in making certain decisions that, although they are the most indicated from the point of view of flight safety, may negatively impact the profitability of the flight. In reality, reducing the workforce is a constant fear of the crew, especially if the pilot has recently made an operational error, and this error may be the reason for his layoff.

> “The company has given too much importance to the financial aspect. With this, the crews were reduced to essential quantities. Sometimes, that decrease causes the extrapolation of the limits of the working day. Besides, much of the spirit of unity

> among pilots that existed before was lost. Now, each pilot tends to care only about himself". (I02).
>
> "In every offshore aviation company, the commercial sector wants to increase revenues, and the operating sector aims to improve aviation safety. The most difficult part of management is to achieve a healthy balance". (I09).

Due to the constant audits and new requirements of the contractor, helicopter transportation service companies have significantly improved their processes. Because of this, they started encouraging their pilots to comply with the safety procedures more rigorously. It makes a massive difference in the pilot's safety behavior when he knows that the organizational culture allows him to notify any failures in the aircraft notebook without worrying about commercial issues or to request a change in flight schedule whenever he feels he is not fit to fly.

However, there is still some pressure on the pilots regarding the notification of possible failures in the aircraft notebook, although that pressure has dramatically diminished over the last years. The term "managing failure" was coined to explain when a small malfunction in one of the aircraft systems is not immediately notified in the aircraft notebook. That failure is considered simple and doesn't directly affect flight safety. It will be repaired between flights or at the end of the day, without leaving the aircraft unavailable. In this situation, the pressure on the pilots to be more "flexible" and keep flying the helicopter is considerable. Needless to say, pilots are sufficiently experienced and competent to know when it is possible to "manage" and what kind of failure can be managed. This practice of flexibilization ends up generating more stress for the flight crew.

> "There is an inconsistency between the company's discourse, which is based on rules and flight procedures, and the company's actual behavior — for example, the transcription of failures in the aircraft notebook. Because the company has strong concerns about profitability, it puts pressure on pilots and mechanics so that smaller malfunctions are not informed in the aircraft notebook, which would set the aircraft unavailable for flight". (I06).
>
> "Some of the best practices that are widespread by the company are just for show. An example of this problem is the launch of malfunctions in the aircraft notebook. The company, through the aviation safety department, propagates that any failure should be launched in the aircraft documentation, and pilots should not fly under those conditions. However, the day-to-day reality is quite different. When a commander notifies a failure in the aircraft notebook, he receives several calls from managers, pressing him to reconsider his decision". (I09).
>
> "Currently, according to the organizational culture, the pilot that notifies certain small failures in the aircraft notebook damages his own reputation among managers. This culture is very dangerous". (I12).

The interviewees perceive an increasing departmentalization within the companies. They complain they have no clue what is going on in other areas of the organization, such as finance and strategy. They also claim that other employees seem not to be aware of the specificities of the flight sector. Moreover, some pilots also notice a division in the company between the administrative and operational sectors. They argue that many administrative staff have no experience with aviation and do not understand the peculiarities of the activity.

> "There is a great distance between each sector – operations, maintenance, management, administration, etc." (I02).
>
> "Recently, the company started to send the flight schedule to pilots in a partial way, that is, only with the flights of that pilot. Therefore, the pilot does not know who the other pilots are, who are flying in that period. This procedure has increased the distance between the crews and has made the interaction even more difficult." (I06).
>
> "The sectors within the company are very isolated. We don't know who works where and in what. The company has grown a lot, and the departmentalization is too much." (I07).
>
> "The company has become very departmentalized, things happen, and we know about them from friends in other companies. Another problem is that those in management positions get into the habit of withholding information and knowledge, becoming indispensable managers, as they do not share knowledge with their subordinate managers. This behavior is intended to perpetuate their position to the detriment of the interests of the company." (I09).

4.2.2 Communication and Power Distance

According to the interviewees, in spite of its recent improvements over the last years, vertical communication within offshore aviation companies still lacks effectiveness. Transparency of communication is still a crucial issue in the sector. Pilots that have already held management positions, such as director of operations or chief of base, reported that, on many occasions, they knew about important company decisions only on the eve of their coming into force. Other interviewees also reckon that there is room for improvement when it comes to the means and ways managers employ to communicate with pilots.

> "The communication between managers and pilots is distant, and in general, the way the information is disseminated is not adequate. Pilots have little voice regarding the company's acceptance of the contractor's requirements, which, more often than not, does not make sense." (I02).
>
> "Communication is not good. Frequently, we wind up knowing the news through other companies' employees." (I16).

Furthermore, because offshore companies operate from a few bases and their workforce works in fortnight shifts, it might seem more convenient to disseminate relevant information through digital platforms (e-mail, apps, etc.). However, the flow of vast amounts of data via e-mail within an organization ends up creating a distortion, as there is no analysis of the effectiveness of this form of communication. Interviewees said that they felt overwhelmed by the quantity and the extent of e-mails sent by their companies. They argue that first, companies need to check if there is enough time for pilots to absorb all that content effectively. Then, it is also paramount to verify if the disclosed information was correctly understood. Pilots also think that the experience of discussing such matters in person in a classroom-type environment would bring many more benefits to their operational improvement and aviation safety as a whole.

To foster sharing operational information among pilots, some companies have established a meeting at the end of every fortnight shift, where some pilots that have just finished their fortnight give a presentation to the other pilots that are initiating theirs. At that meeting, pilots are informed of the changes or mishaps that happened during their time off. Safety measures are also reported on that occasion. Those meetings have contributed to ensuring the safe continuity of flight operations.

Offshore aviation is still largely dominated by male pilots. Female pilots represent less than 5% of the total. This unbalanced situation poses other difficulties to women who venture into this challenging environment.

> “I am one of 6 female pilots out of about 150 pilots in the company. Unfortunately, there is still some prejudice in the industry regarding female helicopter pilots.” (I08).

According to the most experienced interviewees, in the past, the power distance between commanders and copilots was considerable. The situation started to change when consulting firms hired by the MC released their reports highlighting that power distance was compromising aviation safety. Moreover, the Regulatory Agency increased control over CRM training and procedures. Since then, CRM courses have profoundly changed, directly impacting on pilots’ behavior. The market has also become more demanding, no longer tolerating certain mistakes, such as landing on the wrong platform, for example. This has made CRM an essential tool in improving crew performance by reducing the power distance between commanders and copilots.

Nonetheless, CRM is not the single factor that has been contributing to bridging that critical gap. The quality of the young copilots has improved. Young copilots tend to be very familiarized with digital equipment, and this ability has positive impacts on the way they interact with modern digital navigation and communication systems. With more sophisticated aircraft and a more complex aviation environment, copilots have to be much more prepared and professional so as to increase their employability and therefore survive within the sector. Currently, with so many cutting-edge technologies in the cockpit, commander's and copilot’s functions are much more related to monitoring and controlling the digital systems than merely flying the helicopter.

Those three factors together – CRM, copilots’ state of the art technical skills, and standardized procedures have continuously contributed to improving communication among offshore flight crews.

> “As a copilot, I feel very comfortable expressing my opinions to the commanders with whom I share the cockpit. Communication is very forthright and professional.” (I02).

> “Pilots from the younger generations have great ease in operating digital systems of the most modern aircraft, such as the FMS. Copilots’ familiarization with this type of equipment should be widely explored during flights. That is, commanders cannot afford not to take advantage of this valuable human resource.” (I07).

> “Communication is very positive among pilots. Commanders accept a copilot intervention. CRM is used almost in all cases. I do not see the power distance. It should be noted that aircraft are now very automated, which makes the pilot and copilot functions very close to each other.” (I09).

However, several of the more senior pilots lack adequate technical skills, mainly because they are not interested in studying the systems of the aircraft and keeping themselves up to date. Thus, they feel threatened by the younger and better technically prepared pilots. Some interviewees pointed out that this is the main generator of power distance between crew members.

What’s more, during the interviews, it became clear that some copilots feel uneasy when demonstrating their technical skills during flights. Despite some consistent recent improvements in terms of CRM and communication skills, copilots still tend to be criticized when they present their opinions or questions to some commanders.

> “Unfortunately, there are still certain commanders who inhibit their copilots’ initiative in the flight. Some of us, copilots, do not feel confident to take part in the flight in a more positive way.” (I05).

> "I try to respect the maximum autonomy of the copilot, giving him the freedom to perform his function professionally and safely. Unfortunately, many copilots are too much constrained by other commanders and do not feel comfortable with a certain degree of autonomy." (I06).
>
> "When I joined offshore aviation, the organizational culture was very oppressive to copilots. The situation is better now, but there's still a lot of room for improvement." (I15).

Communication heavily depends on the people involved. The personal component is crucial. That is why commanders play a key role in promoting proper in-flight communication. In that sense, companies have fostered an influential culture of standardization, intending to reduce the impact of personality traits on communication.

> "Communication in the cockpit is very dependent on who you are flying with. Some pilots are really quite difficult. They are very arrogant and present an antisocial behavior, making communication in the cockpit very difficult." (I05).
>
> "If there is something personal that is disrupting communication, the situational awareness of the crew during the flight is greatly impaired and may have dangerous consequences for the flight." (I06).

Many interviewees mentioned that each pilot has to trust the competence and discernment of the other pilot with whom he shares the cockpit in order to achieve a balanced division of the workload. Commanders need an attentive co-pilot with initiative, and copilots need experienced and skilled commanders. It is vital that pilots help each other, especially at critical moments of the flight. Hence, an honest and frank dialogue is fundamental. Both commander and copilot are at the same level, although the final decision always belongs to the commander. The copilot should interfere whenever he considers that the commander's decision may have a negative impact on the safety of the flight.

Another crucial aspect to consider is the difference in compensation packages between commanders and copilots. In some instances, depending on the company and the number of flight hours, that difference can reach 100%. One company established three categories of copilots, which made no sense since all copilots performed the same tasks. With recurring copilots' complaints, the firm has recently reduced to 2 copilot categories. This salary gap between commanders and copilots extrapolates the operational aspect of the job since there is a difference even in the meal tickets.

It is generally agreed that, due to their responsibilities, commanders must be rewarded financially. However, the size of that compensation is quite debatable. Some argue that the salary difference between copilots and commanders has always been at the current levels, and it is essential to stimulate copilots to aim at professional success, namely being promoted to commander. Others claim that this salary difference is exaggerated, and it doesn't reflect the workload of each function.

> "It is important that there is a considerable difference in remuneration between commanders and copilots. Copilots must aim to become commanders one day. Otherwise, it would be effortless to be a copilot since the salary would not be much different and with much less responsibility. Closer wages would put copilots in a very complacent situation." (I09).
>
> "The salary difference between commanders and copilots does not influence performance. In my opinion, this difference is fair because of the levels of responsibility." (I11).
>
> "The salary difference between commanders and copilots is huge, and it's detrimental to organizational climate. Copilots become too anxious to achieve the qualifications to be promoted." (I13).
>
> "A considerable salary difference motivates the copilot to seek his professional improvement constantly." (I15).

4.2.3 Standardization and Subjectivity

Offshore aviation in Brazil has undergone an important process of professionalization and transformation. At MC, aviation professionals started to manage the air transportation sector as well as at the helicopter transportation service companies. With the development of the sector, the norms and requirements of the ANAC and the MC started to get more and more rigorous. MC, through outsourced consulting firms, has been conducting audits in offshore aviation companies and assigning scores. These scores, together with the prices offered, are what define the winners of the contract bids. In this way, companies that do not meet the standards established by the audits end up reducing their possibilities of new contracts in the market dramatically. Therefore, one of the solutions that companies have come up with to stay competitive is standardization. By means of standardized procedures, companies have managed to comply with the norms and requirements established by the MC and ANAC.

> "Previously, the MC was very disorganized and did not optimize air transportation. I have already had to take off, for example, only to take 28 kilograms of meat to an oil rig. In fact, normalization and flight optimization have made the operation safer." (I10).

According to some of the interviewees, the lack of a balance between aviation safety and the pursuit of profitability is a severe problem in offshore aviation. They argue that companies are too focused on profit and wind up neglecting essential aspects of the sector. By increasing standardization, those helicopter transportation service companies try to add resilience to the system in order to mitigate the risks of a mishap. The organizational culture incorporates the reasoning that the more standardized procedures there are, the more layers of protection the safety system has, which is not completely true. There are limits. Standardization is not “the silver bullet” for aviation safety. Other measures are also necessary, such as training, investing in new technologies, adequate safety managing, etc. To make matters worse, each contractor has its own set of standardized procedures and rules, which adds confusion to complexity.

Furthermore, this strong organizational culture of standardization of procedures has its "dark side" – the reduction of pilots’ autonomy. This extreme reduction of independence has a serious consequence - the alienation of the individual. The subjectivity in performing a task enriches the performer's experience and generates positive results for the organization in terms of motivation and creativity. Standardization within aviation companies has already extrapolated the reasonable, and it seems that managers are not interested in tipping the balance right between standardization and autonomy. In reality, the autonomous crew member is a healthier employee from the psychological point of view.

Pilots perceive another consequence of the standardization of offshore flights – vigilance. With the advent of the operational flight data monitoring (OFDM), any change in flight patterns provokes questioning by the operations department. That is, if a pilot during a specific moment of the flight goes beyond any limit, such as climb rate or airspeed, this information is saved in the aircraft system, and later on, he will be questioned about that noncompliance. Hence, pilots feel that their flights are being controlled and monitored all the time as if they were in a “big brother reality show.” Despite all the benefits that standardization and the OFDM may bring to aviation safety, interviewees perceive them as a “double-edged sword” that can even lead to their dismissal. Therefore, pilots pay more attention to the OFDM patterns than to the safety of the flight. They know that any tiny mistake can provoke their dismissal. The fear of dismissal has ultimately altered the organizational climate of offshore aviation companies.

> “On one occasion, I was flying with a pilot who did not respect the aircraft flight profile, and, to make matters worse, our destination was a critical platform. Since he

> flew extremely concerned about the OFDM, he ultimately disrespected the flight profile of the aircraft, putting the aircraft at unnecessary risk.” (I14).
>
> “With the fear of unemployment and the employment of the OFDM, many pilots fly more worried about OFDM than about the flight profile of the aircraft or external dangers. Some pilots fly the OFDM; that is, they are more concerned with complying with OFDM parameters than with the safety of their flights.” (I15).

The foreign companies with which the Brazilian helicopter transportation service companies have partnerships are committed to international standards. Thus, operating procedures are practically the same everywhere in the world where these companies operate. Some pilots perceive this standardization of flight procedures as an external imposition that hasn't been adapted to the Brazilian offshore operations context.

> “The company became more controlling, increasing the bureaucracy.” (I07).
>
> “As a rule, in offshore aviation, the operation has become extremely restricted. Since I joined the industry, this trend has intensified.” (I10).

However, according to most interviewees, this exaggerated standardization has led the sector to actual mechanization of the activity, which ends up becoming a strong factor of demotivation for pilots. The mechanization of the procedure stifles the autonomy and creativity of the pilots and is a constant cause for complaints within the aviation companies. The challenge is what to do to adequately balance standardization and autonomy in order to leave room for the production of subjectivity.

> “The robotization of flight procedures has caused a decrease in the motivation of the pilots, especially for the older ones that have operated with much more autonomy.” (I06).
>
> At each new audit process, aviation companies standardized a little bit more, reducing pilots’ margin of flexibility.” (I15).

4.2.4 Motivation and Fear of Unemployment

Most interviewees said they really like to fly. They mentioned intrinsic factors, such as the feeling of freedom, the thrill of flight, and the pride of their flight skills, as the reasons for their zest for flying. Moreover, they consider the activity positively challenging and a way to contribute to the safety and the improvement of the oil and gas industry as a whole.

Motivation has a very positive impact on the pilot’s behavior in the cockpit. The more motivated the pilot is, the more engaged and concentrated on the activity he becomes. In other words, he comes to be more meticulous on the preparation for the flight, studies more the aircraft emergency procedures and limitations, and stays more attentive throughout the flight. Thus, the decision-making process becomes faster and more efficient.

> "I do enjoy flying and feel good in my work environment." (I01).
>
> "I really feel enthusiastic about my profession. I always try to learn more about the aircraft and the operational area. Furthermore, I apply myself to be physically and mentally prepared to handle critical situations in flights." (I02).
>
> "As a pilot of the ambulance aircraft, I feel fulfilled with this activity because it allows me to help others and save human lives." (I13).

Although pilots appreciate their profession, many of them said they are not motivated. Some aspects of offshore aviation that could be improved, but are not, end up reducing the motivation of the crew. Small mechanical or electric failures that go on for a long time without a definitive solution, inadequate comfort conditions, and the lack of support equipment are among the factors that demotivate pilots. Another reason for this lack of motivation is the excessive bureaucracy that has grown too much over the last years. Because they are afraid of losing their jobs, they don't complain to their bosses about the work conditions. Therefore, little do managers know about pilots' dissatisfaction. Without feedback, it is tough for companies to reverse this trend of lower levels of motivation among pilots.

> "Pilots are motivated to fly but lack basic incentives. In reality, support infrastructure is poor. There are broken chairs and toilets, and inappropriate couches in every base of operations." (I07).
>
> "The comfort infrastructure is insufficient. For example, the absence of a suitable toilet, a decent couch, and a vehicle for long rides discourages pilots." (I08).
>
> "The bureaucratic requirement has excessively increased over the past years as a consequence of external audits." (I15).

According to the interviewees, before the crisis of the sector, the work environment used to be very positive. However, the fear of losing jobs has increased the levels of competition among pilots, which, to some extent, has deteriorated the organizational climate within aviation companies. Therefore, pilots realized that they needed to hone their skills if they wanted to keep their jobs. In this sense, pilots' self-study, concerning air traffic rules, aircraft limitations, and ICAO English standards, has consistently improved. Besides, pilots began to show more interest in training, especially during flight simulator sessions.

The increase in competition has another side effect – the emergence of cliques. Given that the most significant current motivation factor is to keep their jobs, pilots tend to form groups in order to survive in that competitive environment. Some cliques are powerful, having direct influence over managers' decisions in terms of hiring and firing. Hence, individuals that don't belong to any circle are much more vulnerable to dismissal.

> "What attracted me to this company was the fact that it was a familial company that had the best working environment for pilots. However, the company has grown a lot, and much of the spirit of the union that existed before was lost." (I02).
>
> "The organizational climate is very competitive, and pilots have become very individualistic. Besides, pilots no longer have the pleasure of flying or doing a good job for their own development. The only concern is to stay alive, professionally speaking." (I11).

The fear of dismissal may compromise the safety behavior of some pilots. They are so afraid of being made redundant that they keep flying even though when they have no physical conditions to do it. On some occasions, pilots omit that they are suffering from a particular health condition so as not to be withdrawn from the flight schedule. Furthermore, offshore aviation companies don't keep extra pilots to be used in case of need. So, if a pilot asks to be removed from any flight, it will cause chaos in the flight schedule. Pilots believe that such a situation could damage their reputation and represent a derogatory mark in their professional records.

> "Everybody is afraid of losing their jobs. One of my colleagues who had sinusitis and clearly was not able to fly omitted this information and did not request the withdrawal of the flight schedule for fear of compromising his job. Another coworker, despite a possible broken arm, continued to fly anyway." (I03).
>
> "Due to the fear of unemployment, a friend, who was going through a high degree of fatigue, omitted that information to his boss and did not complain about the flight schedule nor request any change." (I11).

The dismissal process is cold, and the pilot is taken by surprise. The standard procedure is to maintain secrecy until the end of the fortnight when the pilot is notified, and no further flight is scheduled. The purpose of this practice is to avoid that the dismissal interferes with the pilot's behavior. There is no such thing as a prior notice in offshore aviation. The pilot's reaction to his resignation is unpredictable. In fact, aviation companies are greatly concerned that the fired pilot may cause some embarrassing situation for managers or damage some

equipment or aircraft in a moment of despair. Therefore, when the decision to fire a pilot is made, the dismissed pilot loses access to the network and facilities of the company.
Some pilots perceive that procedure as a lack of consideration and trust in someone who has committed to the company. They also think that, depending on the case, a dismissal can be compared to the loss of a family member. The job loss might be very severe and shocking to some pilots. The other side of the coin is that the dismissal is also disturbing to those who stay in the organization. Some pilots reckon they may be the next in line of layoff. Therefore, that actual possibility of unemployment negatively affects pilots' behavior in flight.

> "For those who stay, dismissal is also traumatic. The organizational climate deteriorates. The pilots fly more tense, fearing they are the next on the list of dismissal." (I01).
>
> "If a pilot is anxious about keeping his job and the working conditions are not good, as it is the case today, although he likes the activity, then he is highly unmotivated." (I04).
>
> "The degree of motivation in today's industry is low. Pilots come to work thinking about how to stay employed." (I09).

The salary losses of recent years have harmed the degree of motivation of pilots, although, on average, the profession is still better paid than most other jobs. With the economic crisis and the spike of unemployment rates, pilots' negotiation power has considerably decreased, which has led to lower compensation packages in the sector. Hence, crew members feel that their firms have undervalued their skills and expertise.

> "With the cut in salary, the category has lost much of the purchasing power." (I08).
>
> "Currently, there is a lot of complaint about wages freeze (the last rise was seven years ago). The union is not very active in the helicopter transportation service sector." (I10).

Currently, pilots perceive high instability in the job market due to the resection of the sector. What's more, MC contracts that were previously five years long are now only two years long. Perhaps because of this instability, many pilots demonstrate a lack of identification with their organizations, as if they were freelancers. Because those pilots don't identify themselves with their companies, they tend to be less dedicated and involved with organizational goals. Another way to see this phenomenon of lack of identification with the organization is that pilots have developed a powerful defense mechanism to withstand frustration and disappointment in case of possible dismissal. This behavior is more common among older pilots. By anticipating their displacement, pilots choose not to put down roots in the company so as to avoid any negative feelings that might arise in case of being made redundant.

> “We do not identify with our company. Actually, we do not feel we are part of it.” (I07).
>
> “Due to the instability of the sector and the risk of unemployment, more and more pilots are considering the career in offshore aviation as a plan b. The plan a should be one’s own business.” (I12).
>
> “I have learned that offshore pilots must have a plan b because there is always the risk of firing.” (I14).

Reduced motivation levels interfere with pilots’ attention to flight details, and can also lead them to more introverted behavior, hampering communication in the cockpit. A motivated pilot fears having to fly with an unmotivated one, because he knows how demanding and risky this flight might become. Pilots consider motivation a significant human factor that impacts their situational awareness and communication skills. Thus, an unmotivated crew tends to be less proficient, which represents an additional risk for the flying activity. Given the causality between motivation and behaviors, the stronger the safety motivation that pilots have, the more willing they are to practice safety behaviors (Chen & Chen, 2014). That is why motivation is paramount to aviation safety.

> Unmotivated pilots have an impaired situational awareness and a reduced capacity of cooperating with the other crew members. Moreover, they tend to be more complacent and overestimate their proficiency. Other pilots are really afraid of sharing the cockpit with them." (I16).

4.2.5 Stress

The offshore helicopter transportation operation has certain risks that make it very unique – flying most of the time over water, landing in a confined space with the presence of gas combustion, and often flying an aircraft at its weight limit, just to name a few. Although interviewees stated that the operation is much safer now than it used to be a decade ago, those risks are still relevant. Therefore, just the operation itself is capable of raising the crew’s stress levels.

During the interviews, pilots said that when they face a new operational environment, such as a new aircraft or another base of operations, their stress levels also increase. Besides, degraded weather conditions and the instability of the landing platform (pitch, roll, heave, and heave rate) were also mentioned as relevant sources of stress. These effects are more perceived in new pilots that struggle to settle in such a challenging environment. Nonetheless, as they become more adapted to the new helicopter and the operational milieu, their stress levels tend to diminish.

> "A change of the pilot's base of operations causes considerable impacts on his work routine and private life as well. Not only does this change mean a completely different operational environment, but it also poses high levels of stress." (I01).
>
> "The offshore flight is very complex and peculiar, so an inexperienced pilot feels this difference a lot and, therefore, goes through high levels of anxiety. Early in my offshore career, I had a hard time sleeping, worried about the next day's flights. After a few months, I got more adapted to the operation, and my stress levels decreased." (I03).
>
> "Since the offshore flight is very standardized and repetitive, any other alteration is a great source of stress." (I16).

Due to offshore flight complexity, drastic changes in flight planning – new destination, the number of passengers, or type of cargo, also pose overwhelming difficulties to flight crews irrespective of their level of experience. Moreover, changes in flight schedule are also important stress generators. Occasionally, pilots are requested to take training sessions during their fortnight off or extend their work fortnight because of sudden schedule changes, which becomes a disconcerting factor for them.

In the particular case of pilots that fly the rescue helicopter, the levels of stress tend to be even higher because of some interesting features of this type of flight. First, the circumstances in which the crew operates is stressful due to the time pressure and death risk of the injured or sick individual. Second, flight conditions are usually riskier (nighttime, incomplete information, etc.). Finally, in general, those pilots fly less (accidents in oil rigs are rare events) and, thus, are less trained for their mission.

Besides, toxicological tests are a source of stress for women because of the need to deliver hair samples every three months. Hair is an essential component of self-esteem and having to get it cut every three months has a mostly negative impact on female pilots.

> "For female pilots, quarterly toxicological tests represent an additional stress factor. This is because it is necessary to provide a considerable amount of hair every three months for these tests. There are impacts on our self-esteem." (I08).

Many interviewees stated that one of the most relevant sources of stress nowadays is the MC. The MC has created so many rules and procedures that any mistake can cause the pilot to be withdrawn from the MC list of reliable crew members (called SISPAT). This list cites the pilots that are allowed to fly for the MC. In other words, once a pilot is out of this list because of a mistake, chances are he will be made redundant sooner or later. For example, if a passenger feels mistreated during a flight and reports the incident, the helicopter commander will be requested to formally explain to his boss what exactly happened. Therefore, pilots feel that their decisions are in check all the time. They fly worried about the consequences of every single detail of the flight.

To make matters worse, each contractor has its own criteria and SOP. This variety ends up generating even more confusion and stress among offshore pilots. The shift of pilots' focus from flight safety to the perception that outsiders have of their performance has a significant impact on pilots' stress levels.

> "In a recent flight with a pilot who was a director, due to the state of the sea and the movement of the platform, we had to go around. Before we even stabilized the helicopter to start a new approach, he was more concerned about informing the passengers what had caused the aborted landing than flying the aircraft safely." (I15).

As of 2015, with the reduction in the number of contracts and the consequent decrease in the workforce, pilots began to fear for their jobs, causing high levels of apprehension and tension. According to Dismukes (2007), stress narrows the span of attention, making individuals focus on the most salient aspects of a particular threat. In this case, the threat of being made redundant compromises pilots' behavior, since some of them are more concerned with not being fired than with performing proficiently.

Because it is too cheap for companies to fire and hire pilots as they see fit, the "ghost" of dismissal is always present in their work environment. This possibility of being fired at any time is the leading cause of stress among pilots. The fear of unemployment ends up generating generalized anxiety among offshore pilots.

> "The big stress factor is the fear of job loss." (I01).
>
> "The main cause of stress is the fear of unemployment." (I05).

As mentioned in section 4.2.1, interviewees have experienced significant pressure regarding the notification of failures in the aircraft notebook. Because of the economic crisis, offshore aviation companies have strong concerns about profitability. Hence, they put pressure on their pilots so that smaller malfunctions are not informed in the aircraft notebook, which would make the aircraft unavailable for flight, having a negative direct impact on revenues. Pilots end up thinking that if they transcribe any failure in the aircraft notebook, the aircraft availability for flights will decrease, there will be a reduction in the company's revenue, and layoffs will most likely happen. The current primary concern of pilots - job loss, also contributes to increasing their levels of stress.

Stress usually restrains pilots' working memory, therefore limiting their ability to contemplate multiple hypotheses or to mentally simulate the outcomes of options (Anca et al., 2010). With high levels of stress, pilots experience episodes of short memory lapses and lack of situational awareness. This phenomenon is particularly worrisome because it has a direct impact on pilots' behavior in flight. Some attention and interpretation errors start to happen more frequently, especially in more complex flights. In this case, pilots tend to forget to follow specific procedures or rules, which may lead to unforeseen mishaps.

> "Stress ends up reflecting on my short-term memory and attention level during all my flights." (I01).
>
> "In some stressful fortnights, I also have memory lapses. I cannot even remember what happened during the entire day of flight due to stress." (I05).
>
> "Recently, my parents were having health problems, and my flight partner was also facing a serious family issue. During one of our flights, we made a mistake that put the aircraft at risk of collision. We noticed the error in time, but this episode proved to me that stress drastically reduces pilots' situational awareness." (I12).

Furthermore, pilots reported a decrease of verbal communication in the cockpit during the period of the dismissals, which is one indication that a crew might have been subjected to high-stress levels. We should bear in mind that the breakdown of communication is one of the most common contributing factors in the causal chain leading to air accidents (Ebermann & Scheiderer, 2013).

> "By the end of each contract, when the company usually fires some pilots, we become less talkative and outspoken in the cockpit. We can't help ourselves from thinking about the possibility of dismissal." (I01).

Unfortunately, helicopter transportation service companies don't have aviation psychologists within their aviation safety department. Therefore, they cannot offer appropriate psychological assistance to pilots who are suffering from high levels of stress. There's no doubt that this initiative could make huge strides in improving pilots' safety behavior. Crew members affected by stress have to manage to find by themselves some psychological help outside their organization without even informing their managers.

4.2.6 Fatigue

According to the most experienced interviewees, a few years ago, offshore helicopter transportation service was not organized. They said that it was very common to see, during the same day, different flights taking passengers (fewer passengers than the aircraft capacity) from the same base to the same oil rig, instead of accommodating all the passengers in a single flight. This practice generated unnecessary flights, which increased the costs and consequently reduced the efficiency of the entire operation. On the other hand, on other occasions, the idea was to make the most out of each flight to the oil platform area. Thus, certain flights had an excessive number of landings and takeoffs, which eventually led to high levels of pilot fatigue, confusion in airspace control, and even collision risks. Nonetheless, as previously cited in section 4.2.1, the organizational culture has changed over the last years and some safety procedures, such as limiting each flight to only two landings in the oil rig region, were put in place in order to optimize the transportation service. After the implementation of those measures, pilots started to feel less tired during the work fortnight, and their perception of safety increased.

> "After the modernization of the sector, we fly fewer hours a day and with cutting-edge aircraft. The automation of these new models led to the reduction of fatigue during the flights. Actually, flights have become safer and more comfortable." (I01).

However, the economic crisis has reduced aviation companies' revenues, which has posed new challenges to the sector. In order to survive in this new environment, companies started to "over-optimize" their resources, especially human resources. Helicopter transportation service firms have reduced their workforce to the minimal necessary to carry out their current contracts. Thus, they don't have operational slack anymore. The main side effect of this "over-optimization" is the increase in fatigue levels among offshore pilots. The workload has reached a level that compromises pilots' period of rest and, consequently, their performance in flight.

> "With the organizational culture of maximum use of pilots, flight schedules have become very exhausting. We wake up very early during the work fortnight. Moreover,

> flights are very repetitive, with very short intervals between them. Sometimes, I don't even have time to go to the bathroom." (I11).
>
> "The work routine is quite exhausting. Therefore, pilots need to stay in good physical conditions to support the demands of the job. Older pilots find it harder to keep up with this pace of work. Waking up too early for a hard-working day is definitely a significant cause of fatigue." (I13).

Currently, helicopter transportation service contracts establish 12 hours of availability for each aircraft per day. Those contracts seek to optimize the use of aircraft and pilots. However, this has led to some problems at lunchtime. Companies started to use the so-called interrupted working daily routine (up to 3 hours of interruption, provided that there is an adequate place for pilots to rest). This practice has generated a tricky situation – the change of the lunchtime schedule. That is, lunchtime is not necessarily during the usual lunch hour. The company provides a small mid-morning snack and, with that, postpones actual lunchtime to after 14:00. The problem is that after that time the restaurants nearby the airfield are already closed. Therefore, pilots end up not having an adequate meal, which increases their levels of fatigue and stress.

> "The 12-hour working day has compromised pilots' lunch hour. Last week, I only had 18 minutes to grab some lunch." (I10).
>
> "For pilots who are flying at lunchtime, the company provides a snack, which is not appropriate. Some pilots have brought their lunch from home. I normally lose weight during my fortnight because of this lack of lunch." (I12).

The practice of "over-optimization" has other downsides. One of them is that the same aircraft is flown by more than one crew on the same day, which might cause confusion and misunderstandings among aircrews, especially when it comes to setting flight information into the aircraft navigation systems and monitoring aircraft performance.

Another issue that was highlighted during the interviews is that sometimes pilots are requested to max out their daily flight-hour limit because there is no other crew to fly. Short-haul pilots normally attribute their fatigue-related problems more to prolonged duty periods and early wake-up times (Caldwell, 2005; Yen et al., 2009; Salas & Maurino, 2010). Since there is no operational slack, in other words, a new team to replace a fatigued one, when a contractor asks for a flight that wasn't previously scheduled, the aviation company employs pilots beyond their flight-hour limit, which leads to alarming fatigue levels.

> "On some occasions, pilots are required to complete missions that go beyond their regulated working hours. Despite the vigilance of public agencies, this practice actually keeps happening." (I02).

> "If the companies had extra highly qualified pilots on the alert to be used in case of flights with a greater level of risk, the activity would be much safer." (I09).

As we mentioned in section 4.2.3, standardization has been overused as a barrier to mitigate all the risks. In reality, managers have perceived standardization as if it were a "silver bullet" against all aviation mishaps. One of the forms of standardization is the bureaucratization of many flight procedures. The "over-optimization" culture, together with bureaucratization, leads to high levels of fatigue. Currently, pilots have to fill in an impressive amount of forms and reports, especially after flights, when they are close to their fatigue limit. During the interviews, they manifested their profound discontentment with this extra workload. The interviewees argued that attributing this task to staff members would reduce pilots' fatigue levels and, consequently, improve their flight performance.

> "The company has generated an excess of bureaucratization and standardization. The number of forms to be filled by pilots has increased dramatically. This practice ends up increasing pilots' workload, which diverts pilots' attention away from the flight." (I07).

> "Pilots are overloaded with administrative tasks, such as filing numerous aircraft and flight reports. That task could be assigned to a dedicated staff." (I10).

> "In my fortnight, I wake up at 04:30 almost every day, which is very tiring. After a 12-hour working day, we arrive at the hotel around 19:00. In addition, the flight schedule is available only at 21:00, when it is then possible to plan the flight for the next day." (I14).

In section 4.2.5, we discussed the fact that pilots experience stress when they encounter a new operational environment – a new aircraft or area of operations. Nonetheless, more often than not, stress and fatigue are different sides of the same coin. Because pilots need to expend a significant amount of energy and time to learn how to operate within this new environment, not only does their level of stress increase, but they also become exhausted.

> "Flying a different aircraft or in another platform area requires a lot of preparation and dedication, which leads to high levels of stress and fatigue. We become worried about our performance in this new environment." (I05).

Sleep-related fatigue was also mentioned during the interviews. Pilots argued that one of the major hurdles they face is to adapt their sleep habits to their work regime of 15 days, followed by the same time off. In general, they have entirely different sleep routines in each period. Because aircrew members have a hard time regularizing their sleep during the working fortnight, they end up feeling more tired and less productive. It is worth mentioning that sleep-deprived pilots tend to bypass rational calculation and take higher risks as well as display lower response speed on psychomotor vigilance tasks (Tourigny et al., 2010).

We should also bear in mind that during their 15 working days, pilots don't have holidays or weekends. They wake up early, have a 12-hour work routine, and fly 8 hours almost every day. By the end of their work fortnight, the levels of tiredness increase, and pilots become very anxious. Consequently, crew members start to neglect important details and procedures during the flight. Offshore flight activity requires pilots to have a high degree of attention and concentration, which is negatively impacted by sleep-related fatigue.

When it comes to physical fatigue in offshore aviation, pilots cited three key causal factors – heat, noise, and vibration. Heat in the southeastern region of Brazil, where the two main oil and gas basins (Campos and Pre-Sal) are located, is quite intense, especially in the summer. Although aircraft have air-conditioning systems, crew members and passengers are regularly exposed to heat due to the lack of adequate infrastructure in the bases of operation or airports. Hence, heat causes considerable physical fatigue throughout the workday. It is common knowledge that vibration and noise are intrinsic characteristics of the rotary-wing. However, offshore pilots are particularly more exposed to these sources of physical fatigue because their flight working routine is quite long – 8 hours a day.

> "Vibration present in the flight of rotary-wing aircraft is enormous. After some training flights, I finally noticed the negative effects of vibration on my mood and performance. Heat is also an important fatigue factor." (I08).
>
> "Vibration in helicopters is a huge source of tiresome. On hot days, it is almost unbearable. It contributes greatly to high levels of fatigue." (I15).

Moreover, pilots stated that some of their abilities that are critical to flying are negatively impacted by fatigue. In other words, abilities that are vital to pilots' performance, such as reaction time, working memory, decision-making, and vigilance, become impaired due to considerable levels of fatigue.

> "The main risk factor of offshore aviation for line pilots is fatigue." (I03).
>
> "Fatigue is the main risk in the operation." (I11).

Some pilots mentioned that, when they feel tired, they experience episodes of lack of attention. They skip one or two checklist items, for example. Their level of vigilance reduces. Other crew members have short-term memory lapses when they are fatigued. They cannot remember whether or not certain information was reported to a flight controller, for instance. The problem-solving process is also compromised by fatigue. Fatigued pilots become quieter and more impatient, which reduces their ability to deal with tricky problems during the flight. In general, pilots tend to underestimate their levels of fatigue and overestimate their flying abilities even when they are exhausted.

> "Fatigued pilots become slower decision-makers. They react more slowly to flight demands, and thus, they are more vulnerable to the risks of the activity. That's why there is a pact between pilots to pay more attention to each other's performance at the end of the fortnight." (I10).
>
> "Tired pilots have a hard time staying vigilant during their flights. To make matters worse, even when they are exhausted, they omit this information from managers and other pilots for fear of losing their jobs." (I13).

According to the majority of the interviewees, the modifications of the law of the aeronaut haven't had any significant impact on offshore pilots' working life, since the focus of those alterations was airline companies. They said that the new standards of time-off and working day limits for aircrew and mechanics had already been part of the offshore aviation for a while.

The most controversial aspect of those amendments is the effectiveness of the fatigue control system. Experienced pilots tend to perceive the amendments more positively than other crew members. In this control system, the time of presentation for the beginning of the working day, the flight hours, and the periods of rest are taken into account to gauge the pilot's fatigue. In theory, the purpose of the fatigue control system is to generate a more equitable distribution of the workload among crew members, by preventing, in a specific day, that one crew becomes overwhelmed whereas another one stays underutilized.

> "Before the modification of the law, I felt exhausted at the end of every working fortnight. Nowadays, I finish my fortnight much less tired, and I recover more quickly during my off-duty period. The fatigue control system represents a significant improvement in pilots' work-life balance." (I01).
>
> "There was virtually no change for offshore pilots. The working hours remained the same. What happened was simply an increase in bureaucracy. We have to fill in control cards that do not always depict reality." (I02).

> "For offshore aviation, there were no significant changes concerning the new law of the aeronaut. Companies are just interested in complying with the regulation." (I13).

Helicopter transportation service companies are in the initial phases of implementing this system. The MC has already established a deadline for those companies to apply such a system. Some companies already employ controls for work and flight hours, equalizing the workload of each crew member, in order to reduce the risk of mishaps due to fatigue.

A few years ago, one of the offshore aviation companies tried to learn and adapt to how commercial aviation companies performed their fatigue control. The problem is that the system that was used to establish the flight schedule was very expensive, and possibly 70% of its functions would be blocked because they were not needed in offshore aviation. Hence, the company came to the conclusion that the system wasn't economically viable for the sector.

The alternative solution was the implementation of a simple system, where the pilot himself launches the parameters of fatigue control on a daily basis. This fatigue self-diagnosis system is a digital platform accessed by cell phone, where pilots report, at the end of the day, their time of presentation, work and flight hours, and period of rest. When the pilot forgets to fill out this virtual form, he receives a warning. In addition to the daily digital reporting, any pilot can also make a voluntary individual fatigue report and refer it to the operations department. Theoretically, if the pilot says he is too fatigued to fly on that specific occasion, the company will replace him. However, this does not happen in practice. Pilots are afraid of saying anything, and even if they did, there wouldn't be spare pilots to replace them.

Pilots expressed criticism about that control system for two reasons. First, a fatigue control system should not depend on self-evaluation because pilots tend to underestimate their levels of fatigue and over-estimate their flying abilities. What's more, pilots are afraid that, by reporting an episode of fatigue, this would represent a flaw in their records and would be taken into account in case of any future workforce reduction. Moreover, according to Salas & Maurino (2010), subjective self-reports of fatigue and sleepiness tend to underestimate actual performance deficits from fatigue, which makes the task of preventing fatigue even more challenging.

Second, pilots think they should be informed of what is done with the data obtained from these forms and reports. Therefore, they would understand the purpose of the program and be more willing to commit to the initiative. They perceive the control system as a program "just for show," not as a tool that would help managers and pilots to mitigate the critical fatigue factors.

> "In practice, this system represents just one more form to be filled out. Pilots don't perceive any practical result of this program." (I07).
>
> "The system is already running. But pilots do not have access to this information. Fatigue control cannot depend on self-assessment, especially in a crisis where unemployment is a constant threat. This is because pilots omit important data for fear of being fired." (I08).
>
> "The problem with the system is that it does not consider the fatigue accumulated during the fortnight, only that of the day. Moreover, the system depends on the self-assessment of fatigue levels. As it is the pilot who must fill in the virtual fatigue form every night, the system ends up making pilots even more tired." (I15).

4.2.7 Human Error

In order to better understand human error and prevent procedure and rule violations, helicopter transportation service companies introduce the concept of "fair culture," where a board of managers and aviation safety experts analyzes pilots' mistakes on an individual basis. The trickiest part of this procedure is to distinguish error from violation. On many occasions, it is a fine line that separates the two. Moreover, we should bear in mind that there is a strong subjective component in this analysis, which makes the final decision even more challenging to reach a consensus within the group.

One of the members of the so-called "fair culture" board is a pilot called "the gatekeeper," who is chosen by the other pilots to represent them in all kinds of flight-related discussions, such as issues with Helicopter Operations Monitoring Program (HOMP) and OFDM systems. In fact, "the gatekeeper" is the pilots' attorney for technical matters. In case of a pilot error, such as a landing on the wrong oil platform, this group will evaluate the pilot's attitude and procedures. The group will check if what happened during the flight was an error or a violation of rules or standard operational procedures. If the board concludes that the pilot committed a violation, the company usually fires him.

> "The company encourages crew members to report errors so as to contribute to the prevention of aeronautical mishaps." (I01).
>
> "Due to the fear of unemployment, pilots tend not to report all faults committed, hiding small ones from their managers." (I03).

> "In the past, companies sought to understand error and learn from it. Currently, with the implementation of the fair culture, they are more concerned to distinguish error from violation, which is sometimes very difficult and complicated." (I04).

The side effect of the "fair culture" concept is that some crew members that mistrust the process prefer to omit a flight mistake for fear that such error might be interpreted as a violation and consequently lead to their dismissal. Pilots fear that by reporting a mistake, instead of contributing to accident prevention, they are providing derogatory remarks to their own job records. Despite the benefits that the initiative of "fair culture" can bring to aviation safety, some crew members don't feel adequately represented in the "fair culture board" and consider some decisions arbitrary.

> "In some cases, the violation occurred because the company pressed the pilot. Error tolerance is very low. Companies are increasingly ruthless with pilot mistakes and more tolerant of crewmembers' rights." (I04).
>
> "I don't see transparency in dealing with error. Profit is more important than safety. The challenge is precisely to balance these two variables. Besides, there is great difficulty in distinguishing the error from the violation." (I06).
>
> "The company applies the concept of fair culture, where a board of aviation safety professionals assesses the pilots' conduct so as to make the outcome as coherent and fair as possible." (I15).

All in all, the fear of losing the job and the lack of trust in the "fair culture" are a dangerous combination for aviation safety. First, as we mentioned in section 4.2.3, pilots are so worried about how any mistake they happen to make is interpreted by the company that they pay more attention to the OFDM patterns than to the safety of the flight. They think that any small mistake may provoke their dismissal, and this fear of dismissal ultimately alters their flight behavior. Second, due to the misperception of the process of "the fair culture board," some pilots have become less proactive when it comes to contributing to aviation safety. In other words, they simply turn a blind eye to mistakes and don't communicate them to the aviation safety sector. Without this essential information, aviation safety specialists cannot develop an adequate accident prevention program. In fact, some pilots were criticized by their colleagues for reporting their own mistakes through aviation safety reports. Those pilots who criticized their peers' attitude ignore the importance of error reports to mishaps prevention. A culture of omitting mistakes is very damaging to aviation safety.

> "In the episode mentioned above (forgetting the landing gear), I was criticized by my colleagues for having reported an error of my own. They think I should have omitted the fact." (I08).

> "In the previously reported episode (altitude error in the pre-salt region), because of what happened, I was removed from the flight schedule for 20 days, received a warning letter, and demoted. The other pilots criticized me for having reported my mistake." (I12).

Not only does the fear of being made redundant make some pilots omit their own mistakes, but they are also more insecure about criticizing systemic errors within the company. When a pilot notices an operational problem, he thinks twice before informing it for fear of contributing to somebody else's dismissal. Hence, the safety management system of the company loses an essential input for the effectiveness of any system – critiques through a report.

Human errors that lead to aviation mishaps are often preceded by extensive periods in which the latent errors or organizational shortcomings gradually increase but remain unrecognized. These shortcomings may be underestimated or are undetected over time, as the risks increase, and the organization gradually drifts toward an accident (Dekker & Pruchnicki, 2014). That's why a safety report is one of the main tools that aviation safety specialists have at their disposal to prevent mishaps. As a safety performance indicator (SPI), safety reports allow safety professionals to get a quantitative feel regarding the consistency of operational safety at any given time (Cusick et al., 2017). Without critical thinking, any system loses a significant amount of its resilience against accidents.

> "Pilots are constantly and overly concerned about doing nothing wrong instead of focusing on flying the aircraft safely. Thus, they adopt a low profile by not criticizing or pointing out any operational problems or safety issues for fear of losing their jobs." (I11).

4.2.8 Pilot and Position Selection

In the offshore aviation sector, any recruitment process is based on what the company needs at that moment for a specific transportation service contract. Because of the economic crisis and the vast availability of unemployed pilots in the market, offshore aviation companies hire their crew members with a short-term mindset. They focus on who they need for now and at the minimum cost. Therefore, companies only look for new pilots when they need to meet the requirements of their new contracts. The hiring process is based on the profile of the necessary pilot in terms of flying qualifications, professional experience, and flight hours.

When it comes to human resources, companies don't look more than two years ahead – the duration of almost all contracts.
This over-optimization of human resources has led aviation companies to seek to reduce the expense of their operations at all costs, including by hiring only the extremely necessary crew members with the minimum needed operational qualifications. Therefore, the number of commanders and co-pilots is the one strictly required to fulfill the current contracts with the lowest possible cost. Although companies comply with all the regulations and the MC requirements for pilots' qualifications, the fact that they invest only the minimum necessary in their human resources might compromise aviation safety levels because of the lack of operational slack.
Another interesting aspect of the hiring process is the influence of managers' indications and recommendations. According to the interviewees, when a new contract is signed, and the company needs more pilots, indications from managers play a crucial role in the recruitment of new crew members. They said that to be hired, a pilot needs to be indicated by one of the managers; otherwise, his chances of having his résumé at least analyzed by the human resources department are minimal. That is why it is tough for a pilot to get a job in a specific company without having meaningful connections in that company.

> "It is useless for a pilot to submit his CV. The selection process is not made that way. The most important asset in the process is the candidate's network. In addition to the pilot's qualifications, managers' indications are fundamental." (I09).

Once a pilot is hired, his training records become the primary formal source of information concerning flight skills that will be taken into account in a promotion process. Once a year, he participates in a flight simulator training program where he is evaluated through theoretical and practical tests. The results are recorded on the pilot's evaluation sheets, which are stored in the operations department. In the case of a selection process for promotion to commander, besides the training records, the flight council (a board composed of the most experienced pilots) also takes into consideration the candidate's time in the company, performance in operational flight checks (line check) and, more importantly, the recommendations of key commanders.
However, some copilots consider the promotion system unfair because of the strong subjective component and the lack of transparency. They argue that the criteria considered in the promotion procedure are not clear, which set the stage for cliques to maneuver in favor

of their members. Because pilots don’t know what skills or qualifications are more valued by the flight council, they can’t commit themselves to improve in those unveiled specific areas. Furthermore, they don’t understand why a certain copilot is promoted to commander, and another one is laid off. The result of this lack of forthrightness is unmotivated pilots who, to some extent, are unable to develop a sense of belonging and emotional commitment to their company.

> “The evaluation of a pilot’s proficiency is done veiledly by seasoned pilots. We don’t receive feedback and, therefore, we don’t know how we can improve.” (I05).
>
> “The only official evaluations that exist are in the simulator training flights. Unfortunately, they are not fair, since the instructors take into account not only your performance in the exercises but also your position in the company.” (I14).

When it comes to dismissal, it works very similarly to the recruiting process. In that sense, the company tries to keep only the smallest possible group of pilots, according to all regulations, and at the lowest cost, which means that cheaper (less skilled) pilots have more chance to stay employed. It is essential to mention that, due to tax and labor expenses, the cost of dismissing a very experienced pilot with many years in the company might be very high, which most of the time makes their replacement by new pilots economically inviable. In spite of the company’s economic approach to dismiss its pilots, cliques have a profound influence over this decision. Cliques' leaders have direct access to top managers and, therefore, can argue in favor of their protected clique members. Unfortunately, those pilots who are not part of any clique are in a disadvantageous position to save their jobs.

> “One of the big problems of the sector is the lack of sound criterion for dismissal. I have seen a technically weaker pilot being kept, instead of other ones with numerous qualifications, just because he was part of a particular clique.” (I08).
>
> “Offshore aviation is a sector where connections are valued more than the pilot's technical skills. In moments of dismissal, the pilots who belong to the right cliques have a greater chance to survive.” (I11).

According to some pilots, the same problem happens when it comes to the selection process for managerial positions. Similar to the promotion proceedings, this process lacks transparency and clearly established criteria. Most of the time, the company doesn’t even inform that the position is available. Hence, highly motivated and ambitious pilots who could become top leaders in the company cannot even apply for senior positions. The perceived lack of opportunity might lead to unmotivated talented employees.

> "Unfortunately, promotions are very political. Indications are more important than qualifications or experience." (I10).

> "A few years ago, I was constantly bypassed for promotion without any official explanation. This is still happening with other copilots but on a smaller scale. I think I have an untapped professional potential that could be very useful to my company. Unfortunately, I have no access to some opportunities, such as managerial positions." (I14).

All in all, the interviewees have perceived companies' attitudes towards human resources as a sign of drop-in pilots' prestige and value. Crew members complained that they are losing ground in their organizations. As far as they are concerned, the fact that companies are dismissing very experienced and talented pilots that are over 65 years old without any sort of recognition is an example of this loss of pilots' importance. Moreover, some pilots think that they are in a disadvantageous position because the number of unemployed skilled pilots has achieved critical levels. In their opinion, helicopter transportation service companies have the upper hand, and therefore, pilots are not adequately treated.

> "Unfortunately, companies are firing pilots over the age of 65 because of an MC requirement. Recently, my company dismissed one of the best pilots of offshore aviation just because he had turned 65." (I01).

> "The company always prioritizes the commercial aspect of every decision. In reality, the company forgets that its greatest asset is the human resources - employees that are willing to give their best to their company." (I04).

> "This has happened because the supply of extremely skilled pilots is vast, and therefore, companies do not have the slightest difficulty in hiring new pilots at the moment they need them." (I05).

Another side effect of the influence of cliques is that the work environment becomes less friendly and unitive. Cliques make an already competitive environment even more difficult for pilots to adapt. Thus, some pilots don't feel comfortable in their organization and, for a different reason from that that we mentioned in section 4.2.4 (fear of unemployment), consider to transitioning to another professional path. This difficulty to feel fully integrated with colleagues due to the power of cliques is a crucial demotivational factor in the offshore aviation sector.

> "Pilots are leaving the offshore aviation sector to fly in the executive aviation in São Paulo, with higher salaries." (I01).

> “Some coworkers are leaving the offshore aviation to seek a position in executive aviation, usually in São Paulo.” (I05).
>
> “Many pilots get tired of the activity and just do not leave it because they have no other option of employment.” (I08).
>
> “Some pilots, I included, don’t feel very welcome by the group and consider the environment not very friendly.” (I10).

4.2.9 Training and Safety Management System

Training programs have consistently evolved over the last decade, mainly because of state-of-the-art flight simulators, where virtually all types of missions or emergencies can be reproduced. Due to the fact that there are flight simulators of the majority of the aircraft that are flown in the country’s offshore sector, the training costs have considerably decreased, which allows companies to invest more and more in their pilots’ proficiency. Nowadays, practically all training flights are carried out in simulators. This type of training is much more comprehensive and effective. We should bear in mind that some maneuvers are too risky to be trained in the actual aircraft.

At least once a year, during a week, each pilot participates in a simulator training program, consisting of two days of theoretical classes, with one final written test, and four simulator sessions, the last one being a check flight. The auditor pilot may be from ANAC, a training service firm, or the offshore aviation company itself. According to the interviewees, companies strive to get the most out of this essential training tool. Their objective is to reproduce during the simulator training the actual flight conditions, so as to allow pilots to train and sharpen their skills in a very controlled operational environment that is almost identical to reality.

Not only have aviation companies improved their training programs in terms of quality, but they have also implemented important changes in the way they schedule the training flights. In the past, it was common for pilots to attend their training sessions during their time off, which was entirely inadequate. This resulted in demotivation and reduced performance in the training flights. The ANAC often fined the companies due to this irregular practice, which eventually led to the change of this situation. Currently, pilots train in their fortnight of work, which has a positive impact on their recovery from fatigue.

However, due to the "over-optimization" culture, it is complicated for managers to conciliate all pilots’ commitments, such as training flights in the simulator, vacations, health tests, instructions, etc. In order to reduce these difficulties, companies are transforming part of the training into distance learning, which does not solve the problem, since the root cause is the small number of pilots to accomplish all the tasks. What’s more, some pilots complained that, although the content of the program is adequate, the manner it is delivered is not efficient, which might lead to gaps in the training process.

> “The training program is very concise and fast, leaving certain gaps in regard to aircraft knowledge and flight practice.” (I02).
>
> “Recently, I was scheduled for a distance learning session in a period that I would be on vacation. The content of the training program is good. However, the way it is organized and applied to pilots is not satisfactory.” (I04).

Training is even more critical to pilots of the ambulance aircraft. First, the conditions under which this type of flight is conducted are much riskier. More often than not, the rescue flight is at night when many airports are already closed, reducing the number of alternative airfields. Because this flight involves people with serious health issues, there is a self-inflicted pressure among the flight crew. Second, pilots of ambulance aircraft end up flying much less over their fortnights of work because rescue flights are a rare event. Therefore, the fact that they fly fewer hours impacts their proficiency, which ends up generating a "curse" on the ambulance flight. Pilots of that type of helicopter perceive their current training programs, as particularly unsatisfactory. The training should be more extensive and frequent, precisely to make up for this gap of a few flight hours carried out during the fortnight over several months.

> “When a line pilot returns from vacation (45 days without flying), he has a readaptation flight. The ambulance pilot often stays months without flying and doesn't have this training opportunity. His company doesn't offer him this flight because it would put the aircraft unavailable for a couple of hours, which would have a negative financial impact.” (I07).
>
> “Anxiety of crew members in saving the sick or injured person at any cost is the most relevant risk factor of the rescue flight.” (I13).

Another recurrent complaint about training is that flight simulator programs are not customized to their operational needs. Typically, helicopter transportation service companies outsource training service firms to provide this kind of program. Those firms have their own instructors and offer a very generic training program without taking into account all their clients’ particular needs. Pilots acknowledge the high quality of the training. However, they consider it somewhat disconnected from the operational reality of their companies.

This problem is even more evident in CRM training. In this case, the cause of the problem is the lack of diagnosis of the company's risk factors. One way to find out those factors is to evaluate the CRM procedures during regular training flights in the simulator. Then, the results should be analyzed by those professionals in charge of the CRM training that will modify it according to these data.

> "Before the training in the simulator, an analysis of the pilot's difficulties and weaknesses should be performed. Thus, the flight instructor could develop a customized program for that pilot, optimizing the entire process." (I08).

> "Training in flight simulators is a little bit schizophrenic – withdrawn from the company's reality. The same maneuvers and emergencies are always trained, whereas the specificities and particular needs of each company are not fully taken into account." (I11).

That is why some of the aviation companies decided to introduce a significant improvement in their programs – they employ their more seasoned pilots as flight simulator instructors. Not only are those pilots aware of the current operations in which the company is involved, but they also know many crew members who they are training. With this initiative, companies aim to tailor training programs to their pilots' needs on an individual basis.

However, as previously mentioned, part of the training programs has been transformed into distance learning. Although distance learning can bring convenience to the training session and save essential resources, the exchange of flight experiences practically disappears.

In section 4.2.2, we discussed offshore companies' tendency to disseminate a great deal of information through digital platforms and some of the drawbacks of that practice. In a nutshell, pilots say that they felt overwhelmed by the amount of information received, and they wish there were some in-person guidance in a classroom-type environment.

Likewise, when it comes to training, pilots also reckon that training programs should include in-person group discussions so as to exchange flight experiences. According to Lin (2012), knowledge brokering is a critical element in providing the necessary information to the company's staff to enable more effective teamwork. It is the process of connecting crew members and building relationships that optimizes sharing needs and knowledge.

Of course, individual training and crew training are key elements to hone flight skills. Nonetheless, group training can also have a positive effect on other human factors, such as motivation and a sense of belonging. Bring those pilots together as a group, at least in part of their training program, could consistently contribute to creating a more cooperative and friendly work environment.

The SMS has also improved over the last decade in the offshore aviation sector. In a recent past, the MC refused to pay for a flight if the pilots decided to return in the middle of that flight due to some safety concern, such as an indication of a warning light or the malfunction of one of the aircraft systems. Back then, for aviation companies, playing safe, by making the most conservative decision during flights, was a synonym of financial losses. This MC stance ended up encouraging pilots to exceed flight safety parameters whenever they felt that a slight deviation from the rules could benefit their company, financially speaking.

Nonetheless, as mentioned in section 4.1, from the reports of the consulting firms outsourced to indicate ways to develop the sector, the MC has changed its approach and adopted many international standards concerning aviation safety. Currently, if the crew decides to interrupt a flight due to safety reasons, the company will still be paid for that uncompleted flight. Hence, pilots are now encouraged to cancel a flight, without fear of causing financial losses to their organizations.

> "When I started in the offshore aviation, if the crew decided to abort the landing on an over-shaking platform and return with all passengers, the MC would not pay for that flight. Fortunately, this situation has completely changed, and it does not happen anymore." (I01).

In spite of these recent and important advancements in aviation safety, there is still room for improvement concerning SMS. Some pilots perceive SMS as a superficial tool that does not integrate all elements of safety. Operational risk safety and occupational safety, environment, and health are treated completely separated in the companies. In fact, because of the way SMS is currently structured in companies, pilots don't consider it as a useful tool that can identify the most relevant risks and then mitigate them. Pilots see SMS as just another bureaucracy needed to comply with MC and ANAC requirements, without substantial impacts on precluding aviation mishaps. SMS lacks more proximity to the day-to-day reality of offshore operations. It should be designed to dive deeply into the company's main risk factors so as to identify and mitigate them effectively.

> "Companies incorporated some idiosyncrasies of the MC directly in the flight procedures without any adequate analysis. This ends up overwhelming the professional at the end of the line - the pilot. Some safety and security measures have become neurotic." (I07).

> "The system does not work well for complex problems. The SMS, on many occasions, is just for show." (I09).

> "Companies have distorted the concept of SMS. There are a clear separation and a considerable distance between operational risk safety and occupational safety, environment, and health." (I14).

Although helicopter transportation service companies have, among their employees, very skilled and diligent aviation safety professionals, they are not willing to invest more than the minimum necessary to comply with the regulations. Many groundbreaking programs do not progress because of the costs involved. For instance, companies don't have aviation psychologists to carry out human factor prevention programs simply because it is not mandatory. To make matters worse, there is a big gap between academia and the offshore aviation sector. Therefore, there is no scientific knowledge being consistently developed in companies with the academic support of universities of think tanks.

> "You do not see research in the offshore aviation sector." (I11).
>
> "The development of the sector requires the recruitment of human factor professionals to support pilots." (I12).

According to some interviewees, the analysis of the companies' risk profile is not efficient. The only concern is to follow the rules and regulations. Companies are not looking for their safety vulnerabilities and in order to implement the respective measures to preclude an aviation accident. To carry out this risk assessment, it is necessary to put in place a taxonomy to classify aeronautical occurrences. With the appropriate methodology and qualified personnel, the data collected would be used to customize training and safety programs according to the company's specific operational needs. Unfortunately, companies are overestimating the contribution of standardization to offshore aviation safety. Although it brings a lot of resilience to the system, standardization is not the answer to all flight safety problems because it is not a "silver bullet," it has its limitations like every operational tool does. That is why a dynamic analysis of safety vulnerabilities is paramount.

The complexity and density levels in air traffic in the offshore sector have been generating new types of human-factor risks. The understanding and detection of those emerging human-factor risks are essential to reduce the number of accidents. By being the primary sources of information to safety personnel, mishap investigations can indicate those trends in human factors, which will act as early warning signs of growing risks (Yan, 2014).

Thus, aviation safety experts should carry out safety programs based on those risk factors, which depend on what the organization's mishap model is. That is why mishap models are crucial to define and mitigate the most critical risks in an aviation company (Deker, 2014). As we discussed in section 1.3, the primary purpose of HFACS is to be a tool used by safety professionals to help identify unsafe practices wherever they may occur within an organization (Miranda, 2018). Therefore, HFACS methodology can bridge the gap between theory and practice and provide a useful and practical framework for identifying and classifying the underlying causes of operational errors in the Brazilian offshore aviation sector.

4.2.10 Perceived Loss of Prestige

Over the last decade, offshore pilots have perceived some alarming changes in the way companies treat and compensate them for their dedication and expertise. They reckon that their organizations don't consider them as indispensable as they used to anymore. This lack of recognition of pilots’ work negatively influences the organizational climate, which creates divisions among employees within the company. Pilots feel excluded from some important decision-making processes and commemorative events. In reality, the distance between top managers and pilots has increased.

> “Recently, the regional director retired. The company had prepared a farewell party for him, but no crew member or mechanic had been invited to this event. The farewell video (a gift to the former director) also had no image of any crew member.” (I12).
>
> “Companies do not value crew members as they should. Recently my company threw a big anniversary party, but there was not a single crew member present in the event.” (I16).

According to the interviewees, skilled and seasoned pilots are no longer seen by the organization as essential agents on whom, to a great extent, the success of the company depends. Pilots think that they play a role that nobody else can perform in aviation companies. Therefore, they should be more valued by their organizations and the sector itself.

> “A few months ago, an outstanding pilot, a real icon of offshore aviation, with 47 years of experience, was dismissed due to his age (65 years old). The company didn’t pay any homage to him, which demonstrates the devaluation of our profession.” (I01).

Some pilots think that this loss of relevance is, in fact, an expected retaliation for a period of time when the number of skilled pilots was small, and the market was growing. Under those circumstances, pilots could impose their will on their managers, having a profound influence over the company's decisions. Currently, the situation is entirely different – the number of unemployed pilots is enormous, and the market is stagnant, which gives the upper hand to aviation companies.

> "I think this perception of loss of importance is actually a response from aviation companies to a recent past when the offshore aviation sector was too dependent on pilots." (I16).

Another factor that has contributed to this perceived loss of influence is the changes in organizational cultures due to the partnership between the local helicopter transportation service companies and international corporations. The most experienced pilots reported that since the arrival of those big foreign firms, there has been a decrease in pilots' wages and influence over the organizations. They think those measures aim to raise companies' profitability by reducing costs and perks.

> "As of the partnership with a foreign group, very focused on profit, the organizational culture has changed. Wages have been reduced, and pilots have lost importance within the company." (I02).

Furthermore, the exaggerated standardization, discussed in section 4.2.3, has stifled pilots' autonomy and creativity, which is a constant cause of complaint. Pilots perceive an imbalance between standardization and autonomy. Therefore, they feel that, to some extent, they have been prevented from contributing to their talent and skills to their organization's improvement. That's why some of them have lost their motivation and interest in the sector.

> "I am very disappointed with offshore aviation. Our profession has no longer any glamor. Pilots are practically mere drivers of conventional means of transportation." (I11).
>
> "In recent years, we have been treated as common machine operators. One of the reasons for this is the high degree of standardization (mechanization) of the company's procedures in conjunction with the OFDM." (I12).

All things considered, with the economic crisis and the consequent alarming unemployment rates, the perceived work environment has completely changed. Pilots reckon their employers do not treat them adequately anymore, the compensation packages have been reduced, and the over standardization of the sector has diminished pilots' satisfaction with their profession.

“The biggest problem in the industry is the mistaken form of management, where crew members do not receive proper recognition and importance within aviation companies.” (I04).

“There was a reduction of about 30% in contracts, and consequently in aircraft and pilots. However, paradoxically, the workload is higher today, with fewer contracts, than it was five years ago.” (I12).

.

5. CONCLUSIONS

5.1 Brief Summary

This study explores the concepts of human factors and their key role in the aviation safety of offshore helicopter transportation service companies through qualitative research. These human factors studied in chapter 2, such as fatigue, stress, organizational culture, motivation, and human error are vital to understand and to predict the behavior of helicopter pilots in the offshore oil and gas environment. Since between 70% and 80% of all aviation accidents are attributable to a human error somewhere in the chain of causation, the more efficient attempts to reduce the aviation accident rates are those that are developed upon a sound understanding and application of human factors. By mapping those human factors and comprehending their implications on pilots' safety behavior, managers and aviation safety professionals would have a better knowledge of the context of the sector and their company specificities. This would enable the design of a more productive SMS, enhance pilots' safety behavior, improve clients' experience, and prevent aviation mishaps due to human errors.

Over the last few years, the Brazilian offshore industry has experienced a considerable reduction in business volume due to the economic and ethical crisis. This new reality has led to a great deal of pressure on companies' aviation safety programs through downsizing and a heavy focus on cost reduction. Nonetheless, a balanced allocation of resources between safety programs and service production is paramount to ensure the viability of the organization. That is why aviation safety is a key factor for companies' survival, reputation, international prestige, as well as for clients' perceived safety risk. Understanding and applying human factors through all three aviation safety approaches – reactive, proactive, and predictive, will contribute to the offshore aviation sector to reach its business goals.

The focus of this study is to identify and understand the main human factors that influence pilots' safety behavior. Currently, modern aviation safety theory aims to comprehend how pilots react to operational situations and interact with new technology and improvements in aviation safety systems. How aircrews are managed affects their attitudes, which, in turn, affects their performance of critical tasks. Consequently, their performance affects the safety and the economic results of the helicopter transportation service company.

In this chapter, we present the final considerations about the research and the information derived from the in-depth interviews. The conclusions about the human factors are not exhaustive, but they help place this study within the broader context of the Brazilian offshore aviation. Finally, possibilities for new studies are suggested.

5.2 Main Findings and Conclusions

The current situation of the Brazilian offshore aviation sector is particularly intriguing because of three main aspects – economic, ethical, and technological. First, since Operation Car Wash, the oil and gas industry has been experiencing an unprecedented economic and ethical crisis with serious repercussions on the way helicopter transportation service companies are managed. In this scenario of a financial crisis, managers tend to neglect the balance between production and protection, allocating disproportionate resources to providing the transportation service at the expense of risk control programs.

Second, the country as a whole has been facing ethical issues that may be considered endemic. For instance, the recent deadly dam disaster of "Brumadinho" is a sad example of how safety measures can be neglected. The full impact of the accident is still being evaluated, but at least 248 people have been reported dead. According to safety and environmental experts, the collapse of this dam, operated by one of the Brazilian biggest mining companies, could possibly have been avoided. Stricter licensing laws and state oversight and the adoption of more modern technology could transform the Brazilian mining sector, making such incidents less likely (De Sá, 2019).

Third, the advent of new technologies, such as satellite-based management, is profoundly transforming the entire airspace control system in many locations around the globe, including the main Brazilian oil rig region – Campos Basin. In order to deal with these technological innovations, managers, air traffic controllers, and pilots need to develop new skills and adapt some of their safety behaviors.

All in all, those three aspects make the current situation of the Brazilian offshore aviation sector unique as well as risky. Helicopter transportation service companies should approach aviation safety in a comprehensive and meticulous way if they want to deal with those unprecedented challenges successfully. Otherwise, safety programs may end up being only "just for show," which in turn would be a recipe for disaster.

In the offshore aviation sector, the first human factor that has a tremendous impact on pilots' behavior and performance is stress, which confirms Vine et al. (2015) findings for airline companies. Among the negative psychological stressors, the fear of being made redundant without early warning is the most impactful. This stressor makes pilots reluctant to make difficult decisions, such as canceling a flight for safety reasons, just because they might reduce the company's profitability. In reality, the job insecurity ends up generating undue self-attribution of financial responsibility.

Furthermore, this fear has other dangerous consequences. Pilots usually omit a physical or emotional condition in order not to be removed from the flight schedule. Because there is no extra flight crew, if in case of necessity, a pilot asks to be removed from a flight, this will cause a real chaos in the flight schedule, as well as the irreparable damage to his professional records.

The other negative work-related stressor that significantly affects pilots' safety behavior is the pressure not to notify minor failures in the aircraft notebook. The term "managing failure," emerged from the organizational culture, is used to describe the company's attempt to transfer to the commander, once again, a responsibility that shouldn't be his. The pressure on pilots to be more "flexible," by not making the aircraft unavailable and continuing the flight, is enormous. Even though pilots are sufficiently experienced and competent to know what kind of failure can be "managed" and under what circumstances, their duty is not to "manage" but to notify every failure immediately, regardless of its gravity. This practice of "flexibilization" ends up generating considerable and unnecessary stress for the flight crew.

Stressed pilots are more likely to experience episodes of short memory lapses and lack of situational awareness, which are particularly alarming due to their direct impact on pilots' behavior in critical moments of the flights. Attention and interpretation errors, especially in more complex flights, can lead to catastrophic consequences. In order to identify those psychological stressors and propose effective countermeasures, companies should have human factor specialists in their aviation safety department.

The second human factor that plays a crucial role in pilots' behavior is the organizational culture. In order to mitigate the risks of aviation accidents, helicopter transportation service companies try to add resilience to the system by increasing the standardization of their procedures. The organizational culture incorporates the reasoning that the more standardized the flight procedures are, the more barriers against mishaps the safety system has. However, standardization is not “the silver bullet” to all offshore aviation safety issues. Other factors, such as training, cutting-edge technologies, and adequate safety management, are also needed if the sector wants to sustain its clients’ perceived safety risk at low levels.

This organizational culture of standardization has two unintended consequences – the reduction of pilots’ autonomy and the constant perception of vigilance. The first effect, the lack of autonomy, might lead to the alienation of the crew member. The subjectivity in performing a task enriches the performer's experience, creates a sense of belonging, and improves motivation and creativity.

Although pilots experience a higher level of job satisfaction when they are in a structured work environment with a clear set of rules and standard operating procedures, as we discussed in sections 2.3.1 and 2.3.4, it seems that this is not precisely the case in the Brazilian offshore aviation sector. According to the interviewees, standardization within aviation companies has reached unacceptable levels, and therefore, should be reevaluated by top managers. By tipping the balance right between standardization and autonomy, companies might set the stage for more autonomous and inspired pilots.

The second effect, the perceived vigilance, leads pilots to think that any change in flight patterns is a reason to be questioned by their managers. Therefore, pilots perceive the monitoring systems not as a tool for their protection and support but as a means of surveillance and control, like they were in “big brother reality show.” That is why crew members pay more attention to the OFDM patterns than to the safety of the flight itself. Many pilots don’t understand the benefits that a balanced standardization and the OFDM can bring to aviation safety, which indicates the necessity of an educational campaign so as to change pilots’ perception.

When it comes to communication, companies have been using digital platforms to disseminate a vast amount of information among their crew members. However, this form of communication hasn’t been as effective as companies might have imagined. In fact, pilots regret the lack of in-person discussion sessions in a classroom-type environment. These sessions could promote open communication and effective teamwork, which are essential components of a strong learning culture. A company with a healthy and robust culture is much more prepared to overcome the operational and economic challenges imposed by the offshore aviation sector. Furthermore, a culture of constant learning is highly beneficial to pilots' behavior and thus should be fostered by top managers.

Unfortunately, these communication problems have contributed to the emergence of departmentalization in offshore aviation companies. Interactions between employees from different sectors of the company haven't been stimulated. So much so that pilots feel entirely isolated from the other departments and complain that managers and administrative staff do not understand the peculiarities of the aviation activity. The synergy among the company's departments seems to be very low. That situation might partially explain why pilots don't demonstrate a sense of belonging towards their organization.

The third human factor that has an enormous impact on pilots' behavior is fatigue. The economic crisis has reduced aviation companies' margins, posing new difficult challenges to the sector. Those companies have decided to "over-optimize" their human resources so as to lower part of their costs. They have cut their workforce to the minimal necessary to carry out their current contracts, which means that there is no operational slack (extra crews) anymore. One of the side effects of that "over-optimization" is the increase in fatigue levels among offshore pilots. Since there is no operational slack, when an unscheduled flight needs to be operated, the aviation company employs pilots beyond their flight hour limits, achieving alarming fatigue levels. When this "over-optimization" encounters the bureaucratization coming from standardization, pilots experience even higher levels of fatigue.

Offshore flight activity requires pilots to have a high degree of attention and concentration. Pilots' abilities that are critical to fly, such as reaction time, working memory, decision-making, and vigilance, become critically impaired when they suffer from substantial levels of fatigue. Tired crew members tend to neglect important details and procedures during the flight. They skip checklist items, and their level of vigilance reduces. Tired pilots have short-term memory lapses and become quieter and more impatient, which reduces their ability to deal with complex and risky situations. However, as fatigue also affects judgment, the degree of fatigue and subsequent performance decrements are frequently unacknowledged or underestimated by pilots. On the other hand, the negative effects of fatigue have been widely studied and proved, and companies "know" that they test their pilots to the limit. This situation tends to reinforce the need for even more ‘extreme standardization,’ fostering a vicious cycle that, in turn, ends up increasing the pilots’ perception of lack of autonomy and isolation.

So as to reduce pilots’ fatigue levels and consequently to improve their performance, companies should consider attributing some pilots’ administrative tasks to other staff members. The current fatigue control system also needs to be redesigned for two reasons. First, the system should not depend on self-evaluation as its primary source of information, and second, crew members should understand what is done with the data obtained from forms and reports. Thus, they will comprehend the purpose of the program and will be willing to commit to the initiative. Fatigue is an area where new technologies, such as human-computer interfaces, can make huge strides in detecting, mitigating, preventing, and predicting fatigue-related risks.

The fourth human factor to be considered is motivation. Besides the critical job instability, pilots reported as the leading causes of the lack of motivation: inadequate work conditions, salary losses, and the lack of transparency of the promotion process. However, since they fear to lose their jobs, they don't complain to their bosses about those work-related issues, which ends up creating a dangerous vicious cycle.

The job instability has also increased competition among pilots, which, to some extent, has deteriorated the organizational climate within aviation companies. This competition has led to the emergence of cliques. Pilots tend to form groups to protect themselves and to survive in that competitive environment. Some circles exert direct influence over top managers’ decisions when it comes to hiring new pilots or promoting or firing current ones. Pilots that don’t belong to any clique might be perceived as not loyal or trustworthy enough by top managers. Therefore, they are much more vulnerable to layoffs or a turbulent career.

It seems that pilots don’t identify themselves with their organizations. In fact, they act as if they were freelancers without any emotional ties with the company. Job instability may be the main reason for this lack of identification. In order to avoid the frustration and disappointment in case of dismissal, some pilots have decided not to develop emotional ties with the company. Since there is no sense of belonging, pilots tend to be less dedicated or involved with organizational objectives and problems.

The more motivated pilots are, the more engaged and concentrated on flying they come to be. They become more meticulous on the flight preparation, diligent to aircraft emergency procedures and limitations, and attentive throughout the flight. Moreover, their decision-making process becomes even faster and more efficient. Unmotivated pilots exhibit more introverted and inattentive behavior, which hinders communication and increases complacency in the cockpit. Pilots with low levels of motivation are less proficient and represent additional costs and risks to their company.

The fifth human factor that strongly influences pilots' behavior is human error. In order to better approach human error and preclude violations of procedures or regulations, offshore aviation companies have applied the "fair culture" process. This is an attempt to analyze unsafe acts as fairly as possible. However, the board of managers and aviation safety experts has the arduous task of distinguishing between error (unintended action) and violation (intended action). This is because, more often than not, it is a fine line that separates an error from a violation. Furthermore, this analysis has a significant subjective component, which might lead to controversial decisions, especially if we consider that violation, in most cases, means termination of the employment contract by just cause.

Unfortunately, some pilots that don't trust the fairness of the process omit their mistakes for fear that they might be interpreted as a violation. In spite of the benefits that the "fair culture" can bring to their own safety, those pilots don't feel represented in the "fair culture" board and consider some of its decisions unreasonable and biased.

The combination of the fear of losing the job and the lack of trust in the "fair culture" is a dangerous threat to aviation safety. Crew members are so worried about how their organization will interpret a mistake that they are more focused on OFDM patterns than on flight safety, which ends up negatively altering their behavior in flight. What's more, because of their misperception of the "fair culture" process, some pilots simply have stopped contributing to aviation safety. Not only do pilots omit their own mistakes, but they don't report systemic errors within the company either.

Nonetheless, aviation safety professionals largely depend on this information to conceive efficient accident prevention programs. That is why a culture of omitting mistakes is very damaging to aviation safety. Only with critical thinking, an SMS could contribute to enhancing the company's resilience against accidents.

The last aspect that needs to be analyzed is the perceived devaluation of offshore pilots by aviation companies. According to the interviewees, the way aviation companies treat and value their pilots has drastically changed over the last decade. They argue that a few years ago, skilled and seasoned pilots were valued as an essential agent on whom, to a great extent, the success of the company used to depend. Currently, pilots perceive that their skills and work are no longer considered essential by their employers, although they think that pilots play a role that nobody else can perform within the company. They feel excluded from some important decision-making processes and commemorative events. Pilots also consider the dismissal process humiliating and embarrassing. The fact that the dismissed pilot immediately loses access to the network and facilities of the company contributes to interviewees' perception of loss of prestige. The reduction of compensation packages is also another sign of this lack of recognition. That's why they reckon their organizations and the industry should value them more.

Some pilots argue that this loss of relevance is, in fact, an expected retaliation for a period of time when the number of skilled pilots was small, and the market was growing. Under those circumstances, pilots could impose their will on their managers, having a profound influence over the company's decisions. This situation has radically changed. The number of unemployed pilots is enormous, and the market is stagnant, which gives the upper hand to aviation companies.

Another possible explanation for this perception of loss in relevance could be that pilots are now experiencing the first effects of a disruptive change that the entire transportation industry is undergoing – the emergence of autonomous vehicles. The world has been experiencing transformative technologies in mobility and smart transportation. Driverless cars have recently or are soon to become a reality, and many companies have also invested in autonomous transportation systems, including electric taxi drones. In this plausible future, aircraft pilots would play a role quite different from that of one decade ago.

During this research study, we perceive a considerable gap between academia and the offshore aviation sector. Apparently, there is no scientific knowledge being consistently developed in companies with the academic support of universities of think tanks. Both helicopter transportation service companies and universities would benefit tremendously from partnerships for scientific research purposes.

That is why CRM training, SMS, and HFACS are powerful tools for offshore aviation companies to mitigate the adverse impacts of the most important human factors on their pilots' behavior. First, CRM is a comprehensive system of applying human factors concepts to improve crew performance that should be customized to the company's operational needs. Besides the high quality, training should also consider the circumstances under which the company operates, taking into account all its specificities.

Hence, it is vital to carry out the diagnosis of the company's risk factors so as to adequately design a tailor-made training program.
The SMS is still perceived as just another bureaucracy necessary to comply with MC and ANAC requirements, without effectively promoting significant changes to operational safety. SMS should be a useful tool that can identify the most relevant risks and indicate the way to mitigate them. Helicopter transportation service companies should take advantage of their skilled and diligent aviation safety professionals and invest more than the minimum necessary in their SMS.
Companies should identify their safety vulnerabilities and implement the necessary measures before an accident happens. To carry out this risk assessment, a dynamic taxonomy to classify aeronautical mishaps is vital. The complexity and density levels in air traffic in the offshore sector have been generating new types of human-factor risks. The identification and understanding of those emerging human factor risks are essential to reduce the number of accidents. Hence, aviation safety professionals should design training and safety programs based on those risk factors that depend on the organization's mishap model. HFACS methodology can bridge the gap between theory and practice and provide a useful and practical framework for identifying and classifying the underlying causes of operational errors in the Brazilian offshore aviation sector.
In spite of the positive outcomes of the Operation Car Wash and other anti-corruption initiatives, the main obstacle to the development of the offshore aviation sector is still the lack of credibility of the country and the offshore industry in particular. Corruption has significantly driven substantial investments away from the offshore sector. Many foreign oil and gas companies are reluctant to invest in Brazil. Therefore, MC remains the leading helicopter transport service contractor with 80 to 90% of all contracts. This lack of competition creates alarming distortions within the sector. The impact of the MC monopoly on this unstable and troubled business environment with reduced profit margins has influenced managers to neglect safety programs. We should bear in mind that the excessive allocation of resources for production at the expense of protection can harm the safety performance of the organization and can eventually lead to serious aviation mishaps.
Furthermore, brand-new technologies, such as the NextGen with ADS-B systems, should bring additional challenges to the sector. The law of unintended consequences is particularly relevant in this scenario, where a new generation of technology offers

solutions to some existing problems while posing new challenges. Thus, the modernization of the airspace control in the Brazilian offshore area through satellite-based systems, though positive in nature, requires the profound study and the vigilance of its potential unintended implications. Otherwise, we may risk ignoring early warnings that would avoid incidents or accidents becoming imminent.

Finally, although safety programs and public speech of the offshore helicopter transportation service companies indicate they deeply champion human factors, our findings suggest that the reality is quite different. These organizations demonstrate, to some extent, a disregard for human factors, especially when they negatively impact profitability. Pilots feel that their organizations don’t value them adequately. They also perceive safety programs as “for show” - a make-believe culture of aviation safety. From the literature review, we can infer that the disruptive transformation of the transportation industry will take at least one more decade to mature, which means that human factors will stay indispensable for a while. Therefore, aviation companies should value their human resources and manage human factors wisely and humbly. Otherwise, chances are that, with the air transportation system becoming more complex and complicated, we will witness current accident rates producing an unacceptable frequency of accidents due to human factors.

5.3 Recommendations for Future Research

This study focuses on the case of a specific sector of the Brazilian aviation industry. In-depth interviews were conducted to know more about how offshore pilots perceive the influence of specific human factors on their behavior and skills. During this study, possibilities for additional research that throw further light on the impact of human factors on aviation professionals’ behavior emerged.

Since only the selected human factors from chapter two were analyzed, there is available literature exploring different relevant factors to pilots’ safety behavior, such as aircraft design, uncrewed aircraft systems or system automation and integration, which may be the theme of future investigations. Furthermore, similar studies in helicopter transportation service companies in other countries may provide more relevance to the results of this study or even cast doubt on them. Future research could also consider different groups of aviation professionals in the offshore industry, such as air traffic controllers and mechanics, so as to expand the sphere of knowledge concerning human factors in the offshore aviation sector, which would contribute to reducing aviation mishaps occurrence.

6. APPENDIX – INTERVIEW SCRIPT

INTRODUÇÃO:
Explicar sobre a pesquisa e metodologia empregada, e citar as perguntas da pesquisa a serem respondidas pelo pesquisador. Assegurar a confidencialidade da entrevista (anonimidade do entrevistado) e explicar a necessidade de se gravar a entrevista (confiabilidade das informações e dos dados compartilhados).

PERGUNTAS INICIAIS:
Por favor, você poderia descrever o seu trabalho (função, aeronaves pilotadas, rotina, atividades desempenhadas, jornada, etc.)?
Há quanto tempo você trabalha na empresa? E na aviação offshore? Por que você trabalha nessa empresa e na aviação offshore?
De que forma a empresa/direção avalia o seu desempenho profissional?

O IMPACTO DOS FATORES HUMANOS NA AVIAÇÃO
Que fatores mais afetam a aviação offshore e, especificamente a sua rotina de trabalho? Explique.

Modelos de Investigação de Ocorrências Aeronáuticas (Somente para Gerência)
Na análise dos relatórios de prevenção e nas investigações de ocorrências aeronáuticas que fatores humanos se apresentam como os mais relevantes? Qual a sua análise desses fatores? Essa tendência se repete em outras empresas do setor? Qual a sua interpretação disso?

Operações Aéreas Offshore
Como você descreveria a atual situação da aviação offshore no Brasil?
Qual a sua percepção quanto à evolução desse setor no Brasil nos últimos anos?
De que forma essa situação afeta o desempenho dos pilotos?
Quais seriam os principais obstáculos para o desenvolvimento do setor?
Você já operou em outros países ou em outros setores da aviação civil? Se sim, poderia descrever as principais semelhanças e diferenças com relação à aviação offshore no Brasil?
Se você pudesse implementar modificações na aviação offshore para aperfeiçoar a segurança de voo, o que você faria? Porque, na sua opinião, isso não é feito?

Nova Lei do Aeronauta
Que alterações a nova lei 13.475 de 2017, que dispõe sobre o exercício da profissão de tripulante de aeronave, trouxe para a aviação offshore? Isso foi positivo ou negativo? Por que?
Que modificações a nova lei do aeronauta pode trazer para o seu trabalho? De que forma ela pode influenciar no desempenho das atividades dos pilotos?

FATORES HUMANOS

Cultura Organizacional: (como as coisas são realmente feitas nesta empresa)
O que a sua empresa diz valorizar e considerar importante no que se refere a segurança de aviação? E o que ela efetivamente demonstra valorizar?
Que diferenças nesse aspecto você identificou com relação a sua ultima empresa?

Você percebeu alguma alteração significativa nas prioridades da empresa nos últimos anos? Explique.
De que maneira a cultura organizacional impacta no seu comportamento como piloto?
Como é realizado o movimento de socialização de novos pilotos na empresa? Quais são a ferramentas e caminhos empregados?
A empresa tem algum sistema ou forma para integrar os novos funcionários? Como o faz? Explique.
No caso da necessidade de desligamento, a empresa possui algum programa de reintegração do funcionário ao mercado de trabalho? Explique.

<u>Comunicação e CRM</u>
Como é feita a comunicação entre a empresa/direção e os pilotos?
Qual a importância da comunicação no cockpit e fora dele?
O que você acha da qualidade da comunicação (eficiente/ ineficiente/ regular)? Explique ou exemplifique.
Como você percebe a predisposição dos copilotos em manifestar suas preocupações e sugestões ao comandante da aeronave?
Como você gerencia sua equipe?
Que lições você aprendeu sobre gerenciamento da tripulação nessa empresa e ao longo de sua carreira?
Que consequências um gerenciamento ineficiente da tripulação pode causar? Como mitigar isso? Exemplifique.

<u>Tomada de Decisão e trabalho em Equipe</u>
Como é a sua relação com seu gerente?
Você recebe feedback de seu desempenho profissional? Com que frequência, de que forma e de quem?
Com relação ao voo, de que forma você gerencia um eventual conflito com o outro piloto? Você poderia dar um exemplo?
Que ferramentas ou metodologia você emprega no processo de tomada de decisão?
De que maneira esse processo impacta no desempenho da tripulação em voo?

<u>Motivação e Comportamento Seguro</u>
Você acha que os pilotos gostam do trabalho que fazem? Exemplifique.
Como você percebe o grau de motivação dos pilotos? Explique.
Você se sente motivado a trabalhar na aviação offshore? Por que?
Você pode gostar do seu trabalho em geral, mas estar em certo momento insatisfeito ou desmotivado? Porque? Explique.
O seu grau de motivação atual interfere no seu comportamento? De que maneira?
Houve alguma mudança recente na empresa que gerou impacto na sua área de atuação? Se sim, descreva.
Quais são os maiores problemas que a sua área enfrenta atualmente? Quais são os maiores problemas que você enfrenta na organização? O que faria diferente? Por que?

<u>Estresse</u>
Na sua visão, quais são as principais fontes de estresse (angústia/excesso de pressão) na sua empresa e no setor?
De que maneira esses níveis de estresse têm afetado o desempenho dos pilotos? Exemplifique.

De que forma a sua empresa busca reduzir os níveis de estresse? E no seu caso particular, que ferramentas você utiliza? Essas medidas têm tido um resultado satisfatório?

Fadiga

Quais são as principais causas de fadiga (cansaço excessivo) na sua atividade profissional? Explique.
Você tem experimentado episódios de carga excessiva de trabalho, problemas com sono ou cansaço demasiado? Se sim, exemplifique.
Como o cansaço excessivo ou o período de repouso insuficiente altera o seu comportamento? Em que períodos do dia ou fases do voo você percebe um maior impacto?
Que medidas contra a fadiga você se utiliza quando percebe os seus efeitos? Explique.

Erro Humano

Ao perceber um erro seu ou de outro tripulante, qual a sua atitude com relação a esse erro? Explique.
De maneira o erro é tratado na empresa? Exemplifique.

GERENCIAMENTO DOS FATORES HUMANOS NA AVIAÇÃO

Seleção de Pilotos

Como você foi recrutado pela sua empresa?
A empresa se concentra em reter pilotos chave, com desempenho muito bom? Como?
Quais as maiores dificuldades em atrair e reter esses pilotos?
Quais as principais razões de pilotos saírem das empresas offshore?

Treinamento

Como funciona o programa de treinamento dos pilotos?
Que modificações no programa de treinamento você percebeu nos últimos anos?
Que sugestões você faria para aperfeiçoar esse programa?

Sistema de Controle de Fadiga

Em que fase está a implantação do sistema de gerenciamento de risco de fadiga?
Que mecanismos são empregados na detecção da fadiga humana?
Que medidas contra a fadiga sua empresa emprega? Você as alteraria de alguma forma? Explique.

SMS

De que forma o Sistema de Gerenciamento da Segurança de Voo contribui com o seu desempenho profissional?
Que recomendações você faria para o aperfeiçoamento desse sistema?

Controle do Risco

Quais são os principais riscos da sua atividade profissional?
Que ferramentas você emprega para gerenciar esses riscos?

Encerramento

Há algum outro assunto ou questão que eu não mencionei até agora, mas que você gostaria de comentar? Se sim, por favor, explique.

7. REFERENCES

AGÊNCIA NACIONAL DE PETRÓLEO (ANP); 2018; **Indicadores de desempenho anuais**; Available at: http://www.anp.gov.br/exploracao-e-producao-de-oleo-e-gas/seguranca-operacional-e-meio-ambiente/dados-de-esempenho/indicadores-de-desempenho. Accessed on 10 August 2019.

ALAM, M. A.; **Cockpit Learning in Power Distant Cockpits: The Interaction Effect of Pilot's Interdependence and Inclination to Teamwork in Airline Industry**; Journal of Air Transport Management; Elsevier; 2014.

ANCA, J.; HELMREICH, R.; KANKI, B.; **Crew Resource Management.** San Diego: Elsevier; 2010.

APPELBAUM, S. H.; FEWSTER, B. M.; **Safety and Customer Service: Contemporary Practices in Diversity, Organizational Development and Training and Development in the Global Civil Aviation Industry**; Management Research News, v.27(10), p.1-26; 2004.

BELK, R.; FISHER, E.; KOZINETS, R.; **Qualitative Consumer and Marketing Research**. London: Sage, 2013.

BIENEFELD, N.; GROTE, G.; **Silence That May Kill: When Aircrew Members Don't Speak Up and Why**; Aviation Psychology and Applied Human Factors, v.2(1), p.1-10; 2012.

BIENEFELD, N.; GROTE, G.; **Speaking up in ad hoc multiteam systems: Individual-level effects of psychological safety, status, and leadership within and across teams**; European Journal of Work and Organizational Psychology, v.23(6), p.930-945; 2014.

BOURGEON, L.; VALOT, C.; NAVARRO, C.; **Communication and Flexibility in Aircrews Facing Unexpected and Risky Situations**; The International Journal of Aviation Psychology, 01 October 2013, v.23(4), p.289-305.

BRASIL, Lei nº 13.475 - **Dispõe sobre o exercício da profissão de tripulante de aeronave, denominado aeronauta**; e revoga a Lei no 7.183, de 5 de abril de 1984. 28 de agosto de 2017.

BRASIL, Comando da Aeronáutica, Centro de Investigação e Prevenção de Acidentes Aeronáuticos (CENIPA). **Helicópteros – Sumário Estatístico 2008 – 2017**. Brasília; 2018.

BRASIL; Força Aérea Brasileira; **DECEA aprimora tráfego de helicópteros no espaço aéreo sobre a Bacia de Campos, no RJ**; 2018; Available at http://www.fab.mil.br/noticias/mostra/32970; Accessed on 13 August 2019.

BUTCHER, JN; **Assessing pilots with 'the wrong stuff': A call for research on emotional health factors in commercial aviators**; International Journal of Selection and Assessment, v.10(1-2), p.168-184; 2002.

CABON, P.; DEHARVENGT, S.; GRAU, J. Y.; MAILLE, N.; BERECHET, I.; MOLLARD, R.; **Research and Guidelines for Implementing Fatigue Risk Management Systems for the French regional airlines**. Accident Analysis and Prevention, v.45, p.41(4); 2012.

CACCIABUE, P. C.; CASSANI M.; LICATA V.; ODDONE I.; OTTOMANIELLO A.; **A Practical Approach to Assess Risk in Aviation Domains for Safety Management Systems**; Springer-Verlag London, 2014.

CALDWELL, J. A.; **Fatigue in aviation**; Travel Medicine and Infectious Disease, v.3(2), p.85-96; 2005.

CALDWELL, J. A.; MALLIS, M. M.; CALDWELL, J. L.; MILLER, J.; PAUL, M.; NERI, D.; **Fatigue Countermeasures in Aviation**; Aviation Space Environ Med; v.80: p.29-59; 2009.

CALDWELL, J. A.; CALDWELL, J. L.; THOMPSON, L. A.; LIEBERMAN, H. R.; **Fatigue and its management in the workplace**; Neuroscience and Biobehavioral Reviews v.96; p.272-289; 2019.

CHARNESS, N.; TUFFIASH, M.; **The Role of Expertise Research and Human Factors in Capturing, Explaining, and Producing Superior Performance**; The Journal of The Human Factors and Ergonomics Society, v. 50, 3: p. 427-432; 2008.

CHEN, C.; CHEN, S.; **Measuring the effects of Safety Management System practices, morality leadership and self-efficacy on pilots' safety behaviors: Safety motivation as a mediator**; Safety Science, v.62, p.376-386; 2014.

CHESTERS, A.; GRIEVE, P. H; HODGETTS, T. J; **Perceptions and culture of safety among helicopter emergency medical service personnel in the UK**; Emergency Medicine Journal, v.33(11), p.801; 2016.

CRESWELL, J. W.; **Research Design: Qualitative, Quantitative and Mixed Methods Approaches**. Sage, 2013a.

CRESWELL, J. W.; **Qualitative Inquiry & Research Design: Choosing among five approaches**. Thousand Oaks, Calif.: Sage, 2013b.

CUI, Q.; LI, Y.; **The change trend and influencing factors of civil aviation safety efficiency: The case of Chinese airline companies**; Safety Science, v.75, p.56-63; 2015.

CUSICK, S. K.; CORTES, A. I.; RODRIGUES, C. C.; **Commercial Aviation Safety**; Sixth Edition; McGraw-Hill Education; 2017.

DAMITZ, M.; MANZEY, D.; KLEINMANN, M.; SEVERIN, K.; **Assessment Center for Pilot Selection: Construct and Criterion Validity and the Impact of Assessor Type**; Applied Psychology: An International Review, v.52(2), p.193-212; 2003.

DAWSON, D.; SEARLE, A. K.; PATERSON, J. L.; **Look Before You Sleep: Evaluating the Use of Fatigue Detection Technologies Within A Fatigue Risk Management System for The Road Transport Industry**; Sleep Medicine Reviews, v.18, n.2, p. 141-152; 2014.

DEKKER, S.; PRUCHNICKI, S.; **Drifting into failure: Theorising the dynamics of disaster incubation**. Theoretical Issues in Ergonomics Science, v.15, p.534–544. Section 3.7.2; 2014.

DEKKER, S.; **Human Factors for a New Era**; Second edition, Boca Raton: Taylor & Francis; CRC Press; 2015.

DEKKER, S.; **The field guide to understanding 'human error'**; Ashgate, 2014.

DEKKER, S.; **The Re-invention of Human Error.** Technical Report 2002-01. Ljungbyhed, Sweden: Lund University School of Aviation; 2002.

DISMUKES, R. K.; BERMAN, B. A.; LOUKOPOULOS, L. D.; **The Limits of Expertise - Rethinking Pilot Error and the Causes of Airline Accidents**; Ashgate, 2007.

DE SÁ, GABRIEL; **Brazil's deadly dam disaster may have been preventable**; National Geographic; 2019. Available at https://www.nationalgeographic.com/environment/2019/01/brazil-brumadinho-mine-tailings-dam-disaster-could-have-been-avoided-say-environmentalists/; Accessed on 13 August 2019.

DOS SANTOS, I. C.; VIEIRA, A. M.; **Communication skills: a mandatory competence for ground and airplane crew to reduce tension in extreme situations;** Journal of Aerospace Technology and Management, 01 September 2010, v.2(3), p.361-370.

DRISKELL, J. E.; MULLEN, B.; **The Efficacy of Naps as a Fatigue Countermeasure: A Meta-Analytic Integration**; The Journal of The Human Factors and Ergonomics Society, v. 47, 2: p. 360-377; 2005.

EBERMANN, H. J.; SCHEIDERER, J.; **Human Factors on the Flight Deck - Safe Piloting Behaviour in Practice**; Spring, 2013.

ERGAI, A.; COHEN, T.; SHARP, J.; WIEGMANN, D.; GRAMOPADHYE, A.; SHAPPELL, S.; **Assessment of the Human Factors Analysis and Classification System (HFACS): Intra-rater and inter-rater reliability**; Safety Science 82, p. 393–398; 2016.

FEDERAL AVIATION ADMINISTRATION (FAA); **Modernization of U.S. Airspace**; Available at https://www.faa.gov/nextgen/; Accessed on 13 August 2019.

FIORINO, F.; **Corporate culture fit 'key' to pilot hiring** (National Business Aviation Association convention) (Cover Story) (Statistical Data Included); Aviation Week & Space Technology, v.157(11), p.56(2); 2002.

FLICK, U.; **An Introduction to Qualitative Research**. (4th ed.). London, UK: Sage, 2009.

FRAHER, A. L; **Airline downsizing and its impact on team performance**; Team Performance Management: An International Journal, v.19(1/2), p.109-126; 2013.

FU, G.; CAO, J.; ZHOU, L.; XIANG, Y.; **Comparative study of HFACS and the 24Model accident causation models**; Petroleum Science, 2017, v.14(3), p. 570.

GANDER, P.; HARTLEY, L.; POWELL, D.; CABON, P.; HITCHCOCK, E.; MILLS, A.; POPKIN, S.; **Fatigue risk management: Organizational factors at the regulatory and industry/company level**; Accident Analysis and Prevention, v.43(2), p.573-590; 2011.

GAUTAM, A.; MATHUR, R.; **Influence of Mindfulness on Decision Making and Psychological Flexibility among Aircrew**; Journal of Psychosocial Research, v.13 (1), p.199-208; 2018.

GOMES, J. O.; HUBER, G. J.; BORGES, M. R. S.; DE CARVALHO, P. V. R.; **Ergonomics, safety, and resilience in the helicopter offshore transportation system of Campos Basin**; Work, 2015, v.51 (3), p.513-536.

GRIFFIN, T.; YOUNG, M. S.; STANTON, N. A.; **Human factors models for aviation accident analysis and prevention**; Ashgate, 2015.

HARDAWAY, C. A.; GREGORY, K. B.; **Fatigue and Sleep Debt in an Operational Navy Squadron**; The International Journal of Aviation Psychology, v.15(2), p.157-171; 2005.

HARRIS, D.; LI, W.-C; **An extension of the Human Factors Analysis and Classification System for use in open systems**; Theoretical Issues in Ergonomics Science, 12:2, 108-128; 2011.

HARSS, C.; KASTNER, M.; BEERMAN, L.; **The Impact of Personality and Task Characteristics on Stress and Strain During Helicopter Flight**; The International Journal of Aviation / Aerospace Psychology; p.301-318; 1991.

HARTZLER, B.M.; **Fatigue on the flight deck: the consequences of sleep loss and the benefits of napping.** Accident Analysis & Prevention; 2013.

HAVLE, C. A.; KILIC, B.; **A hybrid approach based on the fuzzy AHP and HFACS framework for identifying and analyzing gross navigation errors during transatlantic flights (Report)**; Journal of Air Transport Management, 2019.

HOERMANN, H. J.; GOERKE, P.; **Assessment of Social Competence for Pilot Selection.**; International Journal of Aviation Psychology, v.24 (1), p.6-29; 2014.

HOLLNAGEL, E.; PARIÈS, J.; WOODS, D. D.; WREATHALL, J.; **Resilience Engineering in Practice: A Guidebook**; Ashgate; 2011.

HOOLE, C.; VERMEULEN, L. P.; **Job satisfaction among South African aircraft pilots**; SA Journal of Industrial Psychology, v.29(1); 2003.

IAN, S.; **A Desilusão do Mercado Offshore**; Aero Magazine; 2016; Available at: https://aeromagazine.uol.com.br/artigo/desilusao-do-mercado-offshore_2548.html. Accessed on 10 August 2019.

INFRAERO; **Anuário Estatístico Operacional - 2017**. Available at: http://www4.infraero.gov.br/media/674694/anuario_2017.pdf. Accessed on 10 August 2019.

INGRE, M.; VAN LEEUWEN, W.; KLEMETS, T.; ULLVETTER, C.; HOUGH, S.; KECKLUND, G.; KARLSSON, D.; AKERSTEDT, T.; **Validating and Extending the Three Process Model of Alertness in Airline Operations**; v.9(10); 2014.

INSUA, D. R.; ALFARO, C.; GOMEZ, J.; HERNANDEZ-CORONADO, P.; BERNAL, F.; **A framework for risk management decisions in aviation safety at state level**; Reliability Engineering & System Safety, v.179, p. 74-82; 2018.

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO); **The Manual for the Oversight of Fatigue Management Approaches**; DOC 9966; C.F.R; 2016.

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO); **Safety Management Manual**; DOC 9859; 2018.

JAZZAERO; **O que é o sistema ADS-B? Automatic Dependent Surveillance-Broadcast**. 2019; Available at https://jazzaero.com.br/aviacao-experimental/sistema-ads-b/; Accessed on 13 August 2019.

JI, M.; YOU, X.; LAN, J.; YANG, S.; **The Impact of Risk Tolerance, Risk Perception and Hazardous Attitude on Safety Operation Among Airline Pilots in China**; Safety Science; Elsevier; 2011.

KIERNAN, K.; **Calculating the Cost of Pilot Turnover**; Journal of Aviation/Aerospace Education & Research, v.27(1), p.49-69; 2018.

KOLBE, M.; GROTE, G.; BARSHI, I.; SALAS, E.; WEINGER, M. B; SMITH-JENTSCH, K.; BIENEFELD, N.; **Human Factors Training in Aviation And Healthcare: What We Know Works Best and How to Put It into Practice**; Proceedings of the Human Factors and Ergonomics Society Annual Meeting, v.55(1), p.2105-2108; 2011.

KOONCE, J. M.; **Human Factors in the Training of Pilots**; London; New York: Taylor & Francis, 2002.

KRAKENES, T.; EVJEMO, T. E.; HABREKKE, S.; HOME, A. S.; **Helicopter Safety Study 3 – limited update of HSS-3 focusing on the period 2010-2015**; SINTEF, 2017.

LANDRY, S. (Ed.); **Handbook of Human Factors in Air Transportation Systems**; CRC Press, Taylor & Francis; 2018.

LEE, S.; KIM, J. K.; **Factors contributing to the risk of airline pilot fatigue**; Journal of Air Transport Management; v. 67, p. 197-207; 2018.

LIN, Y.; **Knowledge brokering for transference to the pilot's safety behavio**r; Management Decision, v.50(7), p.1326-1338; 2012.

LOEWENTHAL, K. M.; EYSENCK, M.; HARRIS, D.; LUBITSH, G.; GORTON, T.; BICKNELL, H.; **Stress, distress and air traffic incidents: job dysfunction and distress in airline pilots in relation to contextually-assessed stress**; Stress Medicine, v.16(3), p.179-183; 2000.

LYNDON, A.; **Communication and Teamwork in Patient Care: How Much Can We Learn From Aviation?**; Journal of Obstetric, Gynecologic & Neonatal Nursing v.35, n.4, p.538-546; 2006.

MAKAROWSKI, R.; MAKAROWSKI, P.; SMOLICZ, T.; PLOPA, M.; **Risk profiling of airline pilots: Experience, temperamental traits and aggression**; Journal of Air Transport Management, v.57, p.298-30; 2016.

MARCUS, J. H; ROSEKIND, M. R; **Fatigue in transportation: NTSB investigations and safety recommendations**; Injury Prevention, 2016.

MARTINUSSEN, M; HUNTER, D. R.; **Aviation Psychology and Human Factors**; Second edition; Boca Raton: Taylor & Francis, CRC Press; 2017.

MELAND, A.; ISHIMATSU, K.; PENSGAARD, A. M.; WAGSTAFF, A.; FONNE, V.; GARDE, A. H.; **Impact of Mindfulness Training on Physiological Measures of Stress and Objective Measures of Attention Control in a Military Helicopter Unit**; The International Journal of Aviation / Aerospace Psychology, p.191-208; 2015.

MELLO, M. T.; ESTEVES, A. M.; PIRES, M. L. N.; SANTOS, D. C.; BITTENCOURT, L. R. A.; SILVA, R. S.; TUFIK, S.; **Relationship between Brazilian airline pilot errors and time of day**; Brazilian Journal of Medical and Biological Research; 2008.

MIRANDA, A. T.; **Understanding Human Error in Naval Aviation Mishaps**; Human Factors and Ergonomics Society; v.60, n.6, p.763–777; 2018.

MONTEIRO, F.; ALBUQUERQUE, T.; **Doing Business in Brazil after Operation Car Wash**; ISEAD; 2018.

MULLER, R.; WITTMER, A.; DRAX, C.; **Aviation Risk and Safety Management - Methods and Applications in Aviation Organizations**; Springer International Publishing Switzerland; 2014.

NORWEGIAN PETROLEUM SAFETY AUTHORITY; **Trends in Risk Level in the Petroleum Activity: Summary Report 2017**. Norwegian Continental Shelf. Norway 2017.

OIL AND GAS UK; **UK Offshore Public Transport Helicopter Safety Record 1981-2010**. United Kingdom; 2011.

OIL AND GAS UK; **UK Health and Safety Record 2018**. United Kingdom; 2018.

PATON, G.; **More than half of airline pilots 'fly while tired'** (News); The Times (London, England), p.15; 2016.

PAULEY, K. A.; O'HARE, D.; MULLEN, N. W.; WIGGINS, M.; **Implicit Perceptions of Risk and Anxiety and Pilot Involvement in Hazardous Events**; The Journal of The Human Factors and Ergonomics Society, v. 50, 5: p. 723-733. 2008.

RADSTAAK, M.; GEURTS, S. A. E.; BECKERS, D. G. J.; BROSSCHOT, J. F.; KOMPIER, M. A. J.; **Work Stressors, Perseverative Cognition and Objective Sleep Quality: A Longitudinal Study among Dutch Helicopter Emergency Medical Service (HEMS) Pilots**; Journal of Occupational Health, v.56; 2014.

RADSTAAK, M.; GEURTS, S. A. E.; BECKERS, D. G. J.; BROSSCHOT, J. F.; KOMPIER, M. A. J.; **Recovery and Well-Being Among Helicopter Emergency Medical Service (Hems) Pilots**; Applied Ergonomics, v.45(4), p.986-993; 2014.

RAJIB, S. U.; FAN, L.; **A study on the critical factors of human error in civil aviation: An early warning management perspective in Bangladesh**; Management Science Letters, v.5(1), p.21-28; 2015.

REASON, J.; **Managing the risks of organizational accidents.** Aldershot, England; Ashgate, 1997.

REINACH, S.; VIALE, A.; **Application of a human error framework to conduct train accident/incident investigations**; Accident Analysis and Prevention 38, p. 396–406; 2006.

REIS, C.; MESTRE, C.; CANHĀO, H.; GRADWELL, D.; PAIVA, T.; **Sleep and Fatigue Differences in the Two Most Common Types of Commercial Flight Operations**; Aerospace Medicine & Human Performance, v.87 (9), p.811-816; 2016.

REMAWI, H.; BATES, P.; DIX, I.; **The relationship between the implementation of a Safety Management System and the attitudes of employees towards unsafe acts in aviation**; Safety Science Journal v.49, p.625–632; 2011.

RITCHIE, J.; LEWIS, J.; **Qualitative Research Practice: A Guide for Social Science Students and Researchers**. Thousand Oaks, CA. SAGE publications, 2003.

SALAS, E.; MAURINO, D. E. (Ed.). **Human Factors in Aviation**. 2nd ed. Burlington: Elsevier, 2010.

SALLINEN, M.; SIHVOLA, M.; PUTTONEN, S.; KETOLA, K.; TUORI, A.; HARMA, M.; KECKLUND, G.; AKERSTEDT, T.; **Sleep, Alertness and Alertness Management Among Commercial Airline Pilots on Short-Haul And Long-Haul Flights**. (Report); Accident Analysis and Prevention, v.98, p.320; 2017.

SEAGER, L.; SMITH, D. W.; PATEL, A.; BRUNT, H.; BRENNAN, P. A.; **Applying aviation factors to oral and maxillofacial surgery – the human element**; British Journal of Oral and Maxillofacial Surgery, v.51, n. 1, p. 8-13; 2013.

SEXTON, J. B.; THOMAS, E. J.; HELMREICH, R. L.; **Error, stress, and teamwork in medicine and aviation: cross sectional surveys**; British Medical Journal, v.320(7237), p.745; 2002.

SHAPPELL, S., DETWILER, C., HOLCOMB, K., HACKWORTH, C., BOQUET, A., & WIEGMANN, D. A. **Human Error and Commercial Aviation Accidents: An Analysis Using the Human Factors Analysis and Classification System**. The Journal of The Human Factors and Ergonomics Society, v. 49, 2: p. 227-242; 2007.

SILVA A., CORREA E.; VARGAS, J.; CHEREM, R.; SILVA JUNIOR, O.; POSSI JUNIOR, R.; **Fatores Humanos Contribuintes para Ocorrência de Acidentes nas Operações Offshore**; R. Conex. SIPAER, 2011.

SKYBRARY; **Cockpit Automation – Advantages and Safety Challenges**; Available at https://www.skybrary.aero/index.php/Cockpit_Automation_-_Advantages_and_Safety_Challenges; Accessed on 15 August 2019.

SOUZA, M. R. C.; RUSSOMANO, T.; **Experiência na utilização do modelo HFACS (Sistema de Análise e Classificação de Fatores Humanos) na estruturação de mapas causais de eventos adversos**; Aviation in Focus – Journal of Aeronautical Science, v.8(1), p.14-18; 2017.

STAKE, R. E.; **Qualitative Research: Studying How Things Work**. New York: The Guilford Press, 2010.

STOLZER, A. J.; HALFORD, C. D.; GOGLIA, J. J.; **Safety Management Systems in Aviation**; Ashgate Studies in Human Factors for Flight Operations; Ashgate, 2008.

STRAUCH, B.; **Investigating Human Error - Incidents, Accidents, and Complex Systems**; 2nd edition; CRC Press; 2017.

TAYLOR, J. C.; THOMAS III, R. L.; **Toward Measuring Safety Culture in Aviation Maintenance: The Structure of Trust and Professionalism**; The International Journal of Aviation Psychology, v. 13, n. 4; 2003.

TOURIGNY, L.; BABA, V. V; WANG, X.; **Stress episode in aviation: the case of China**; Cross Cultural Management: An International Journal, 09 February 2010, v.17(1), p.62-78.

UNITED STATES NAVAL SAFETY CENTER – USNST. **Human factors analysis and classification system (HFACS): A human error approach to accident investigation,** OPNAV 3750.6R (Appendix O). 2001.

VAN DRONGELEN, A.; VAN DER BEEK, A. J.; HLOBIL, H.; SMID, T.; BOOT, C. R. L.; **Development and Evaluation Of An Intervention Aiming To Reduce Fatigue In Airline Pilots: Design Of A Randomized Controlled Trial**; BMC Public Health, v..13 (1), p.1-10; 2013.

VERGARA, S. C.; **Projetos e Relatórios de Pesquisa em Administração**. São Paulo: Atlas, 2005.

VIDULICH, M. A.; TSANG, P. S.; FLACH, J. M.; **Advances in Aviation Psychology**; Ashgate, 2014.

VILLAS BÔAS P.; **A relação entre instituições, fatores humanos e segurança operacional na aviação**; Aviation in Focus – Journal of Aeronautical Science July-December 2014, v.5, n.2, p.68-77.

VILLELA, B. T.; **Applying Human Factors Analysis and Classification System (HFACS) to Aviation Incidents in The Brazilian Navy**; Embry-Riddle Aeronautical University, 2011.

VINE, S. J.; UIGA, L.; LAVRIC, A.; MOORE, L. J.; TSANEVA-ATANASOVA, K.; WILSON, M. R.; **Individual reactions to stress predict performance during a critical aviation incident**; Anxiety, Stress & Coping, 2015, v.28 (4), p.467-478.

WEISSMULLER, J. J.; DAMOS, D. L.; **Improving the Pilot Selection System: Statistical Approaches and Selection Processes**; The International Journal of Aviation Psychology, v.24(2), p.99-118; 2014.

WIEGMANN, D. A., & SHAPPELL, S. A.; **A human error analysis of commercial aviation accidents using the human factors analysis and classification system (HFACS)** (DOT/FAA/AM-01/3). Washington, DC: Federal Aviation Administration, Office of Aviation Medicine; 2001.

WIEGMANN, D. A., & SHAPPELL, S. A.; **A human error approach to aviation accident analysis: The human factors analysis and classification system**. Aldershot, Great Britain: Ashgate; 2003.

WIEGMANN D. A.; ZHANG. H.; VON THADEN, T. L.; SHARMA, G.; GIBBONS, A. M.; **Safety Culture: An Integrative Review**; The International Journal of Aviation / Aerospace Psychology, p.117-134; 2004.

WIEGMANN, D. A.; SHAPPELL, S. A.; **Human Error Perspectives in Aviation**; The International Journal of Aviation Psychology, v.11, n.4; 2001.

WILSON, G. F.; CALDWELL, J. A.; RUSSELL, C. A.; **Performance and Psychophysiological Measures of Fatigue Effects on Aviation Related Tasks of Varying Difficulty**; The International Journal of Aviation / Aerospace Psychology, p.219-247; 2007.

WISE, J. A., HOPKIN, V. D.; GARLAND, D. J.; **Handbook of aviation human factors**; CRC Press; 2nd ed; 2010.

WU, A. C.; DONNELLY-MCLAY, D.; WEISSKOPF, M. G.; MCNEELY, E.; BETANCOURT, T. S.; ALLEN, J. G.; **Airplane pilot mental health and suicidal thoughts: a cross-sectional descriptive study via anonymous web-based survey**; Environmental Health: A Global Access Science Source, v.15, p.1-13; 2016.

XUE, Y.; FU, G.; **A modified accident analysis and investigation model for the general aviation industry: emphasizing on human and organizational factors**; Journal of Safety Research, 2018, v.67, p.1-15.

YAN, J.; HISTON, J.; **Identifying Emerging Human Factors Risks in North American Airline Operations: A HFACS Analysis of Accident and Incident Investigation Reports**; Proceedings of the Human Factors and Ergonomics Society Annual Meeting, v.58(1), p.120-124; 2014.

YAZGAN, E.; YILMAZ, A. K.; **Designing Flow Chart for Aircraft Type Training in Aviation Training Process Management**; Aircraft Engineering and Aerospace Technology, v.90(9), p.1346-1354; 2018.

YEN. J. R.; CHIUNG-CHI HSU, C. C.; ANG, H.; HO, H.; **An investigation of fatigue issues on different flight operations**; Journal of Air Transport Management, v.15, n. 5, p. 236-240; 2009.